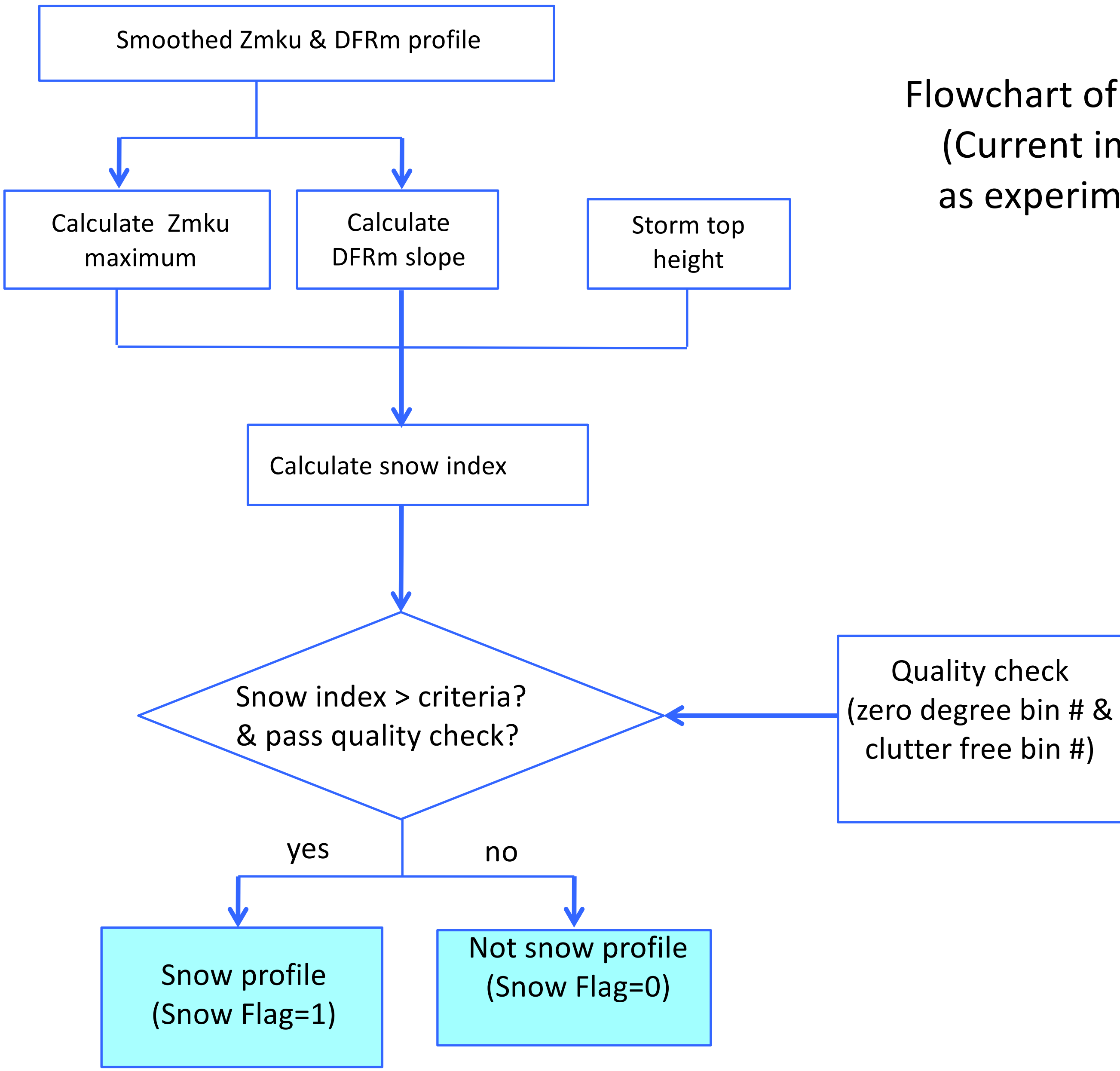
Surface snowfall identification using dual-frequency profiles

Chandra and Minda Le

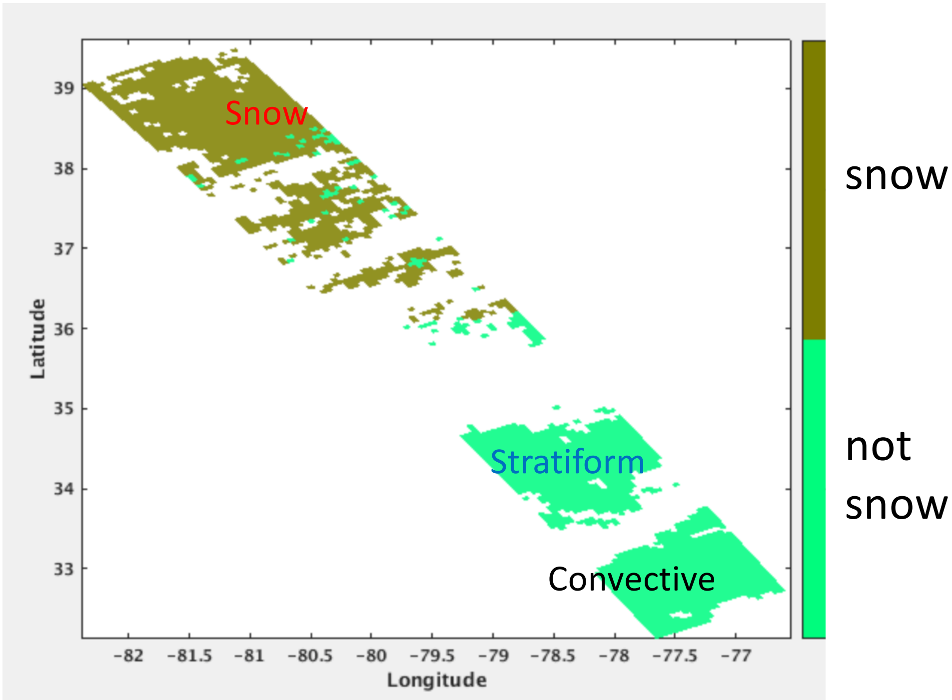
CSU

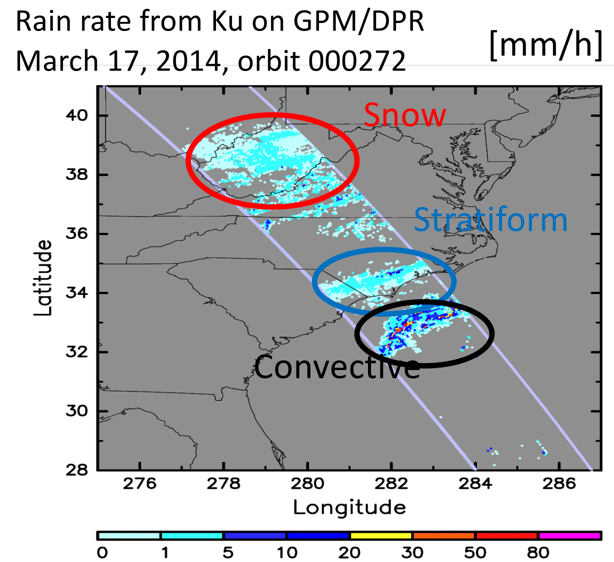
Surface snowfall detection algorithm using snow index

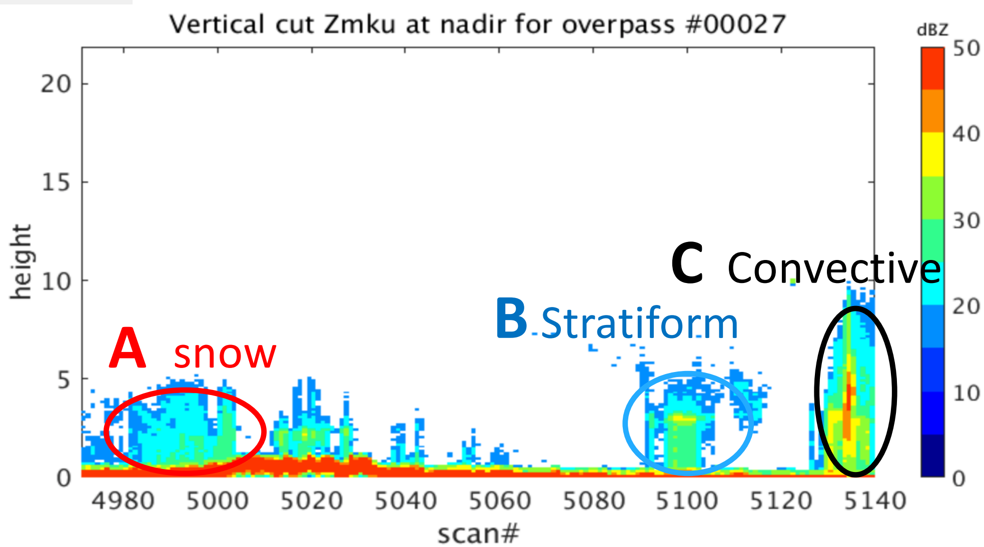


Flowchart of the algorithm
(Current implemented
as experiment version)

Sample performance



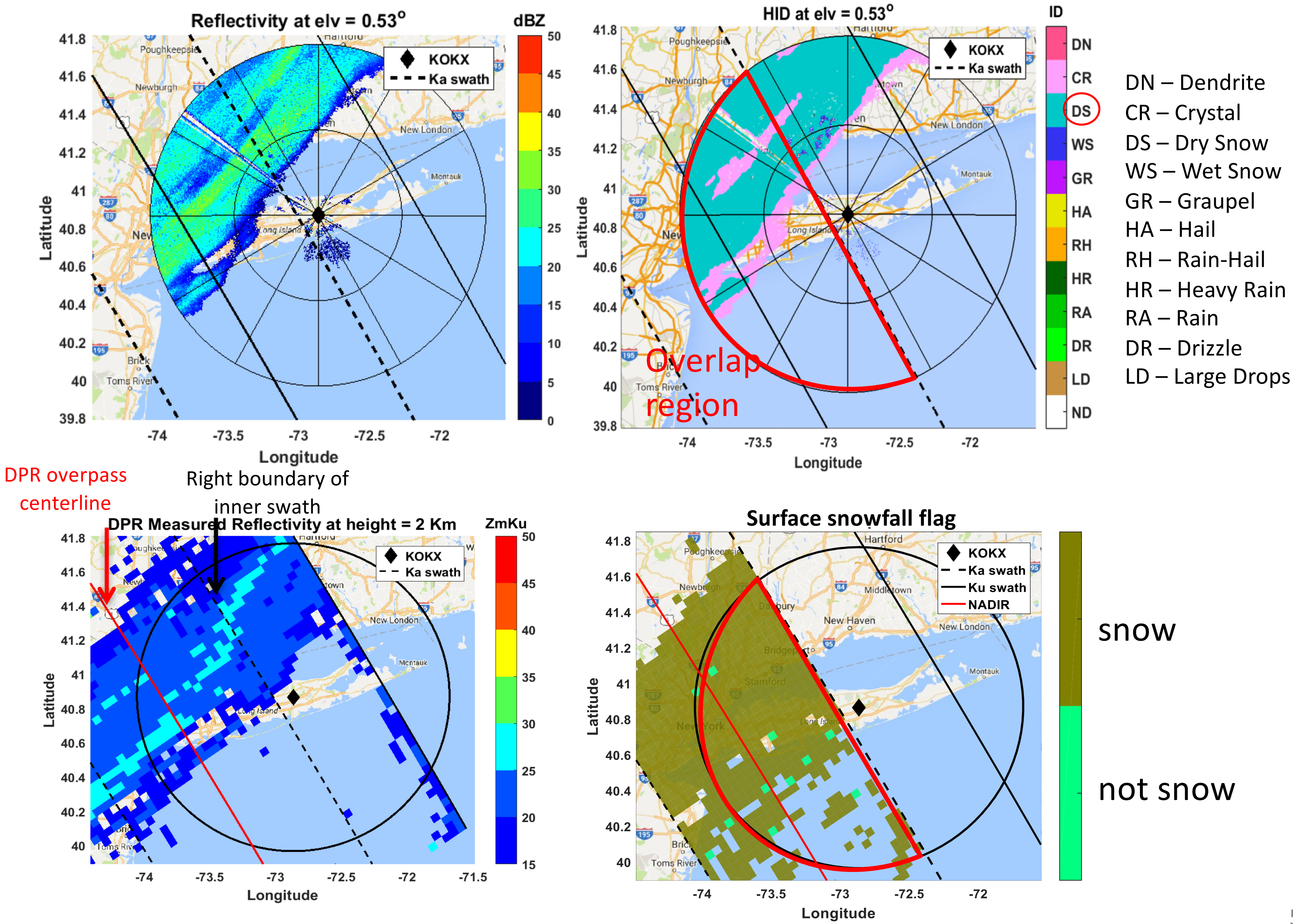


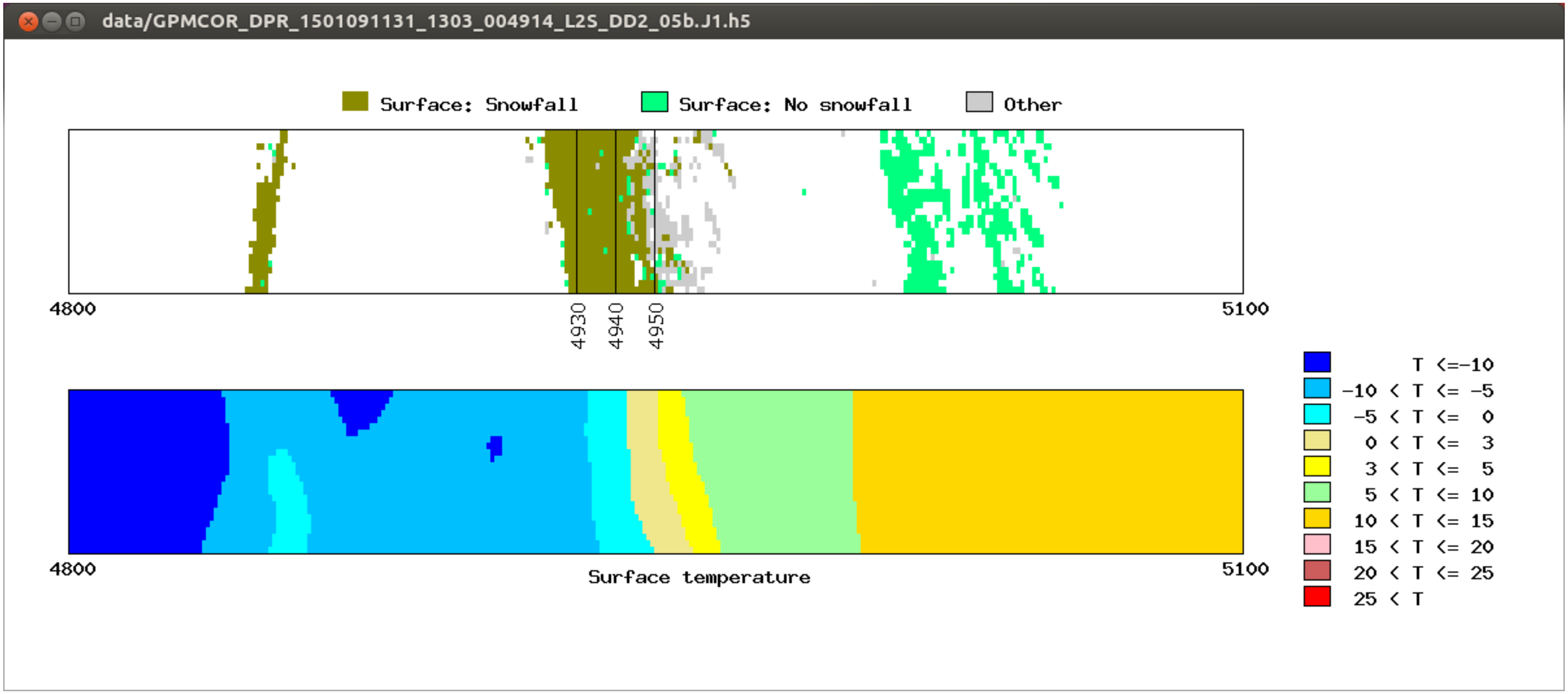


Ground validation sample case: GPM overpass #4914 with KOKX Radar at Upton, NY

Date: Jan 09, 2015 Time: 12:24:55 UTC

Hydrometeor class from ground radar matches well with surface snowfall identification method





Alternate Verification: Orbit # 4914

Path Attenuation Estimates for the DPR

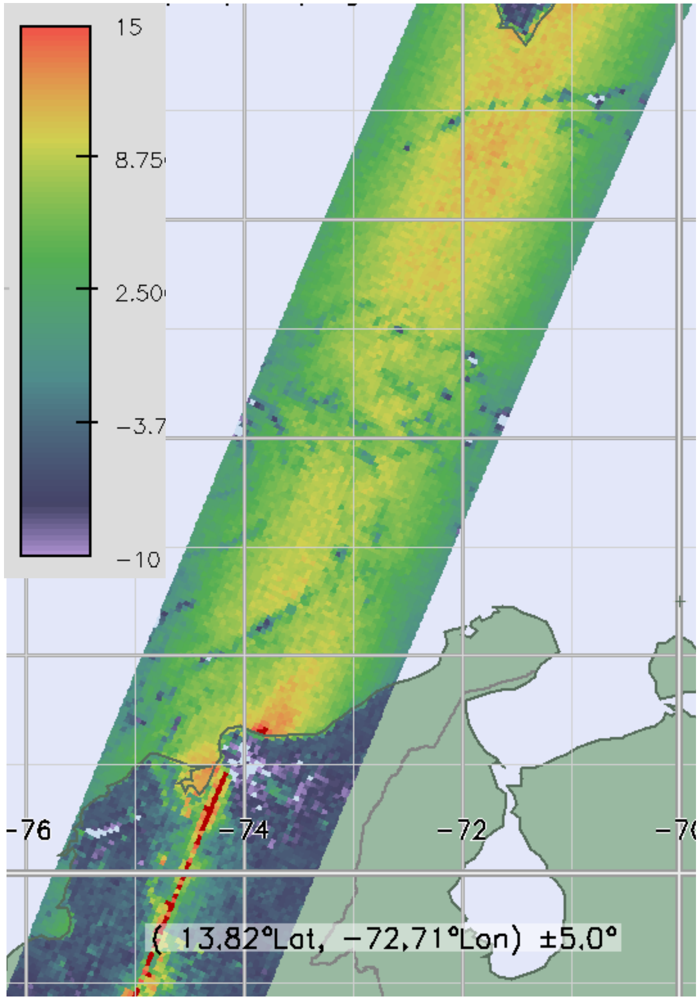
Robert Meneghini[1], Hyokyung Kim[2], Liang Liao[2]

1. NASA/GSFC, Code 612

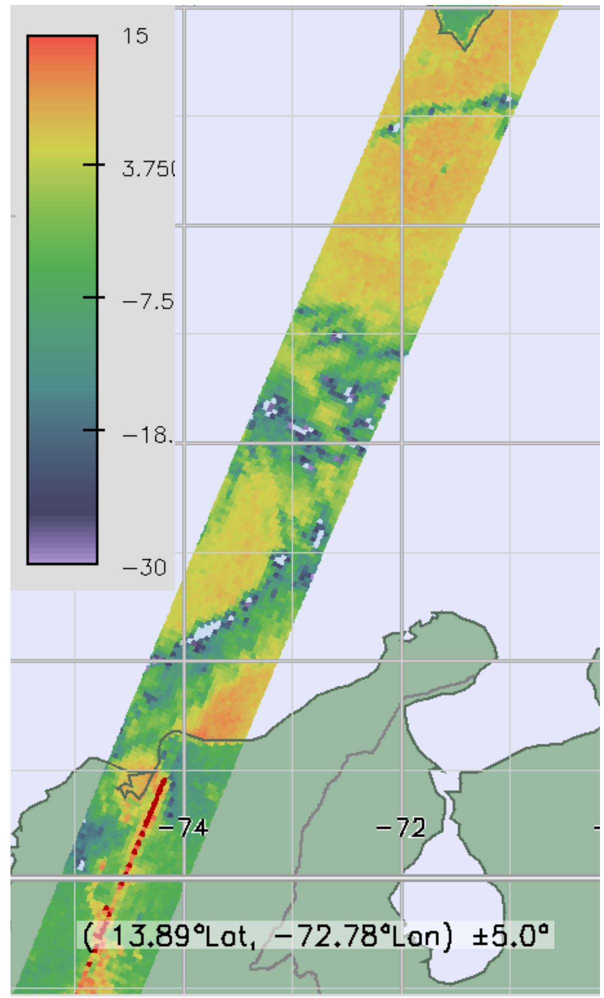
2. Morgan State University/GSFC, Code 612

Outline

- Background & Status
- Reduction in variability of reference data
- NUBF Mitigation

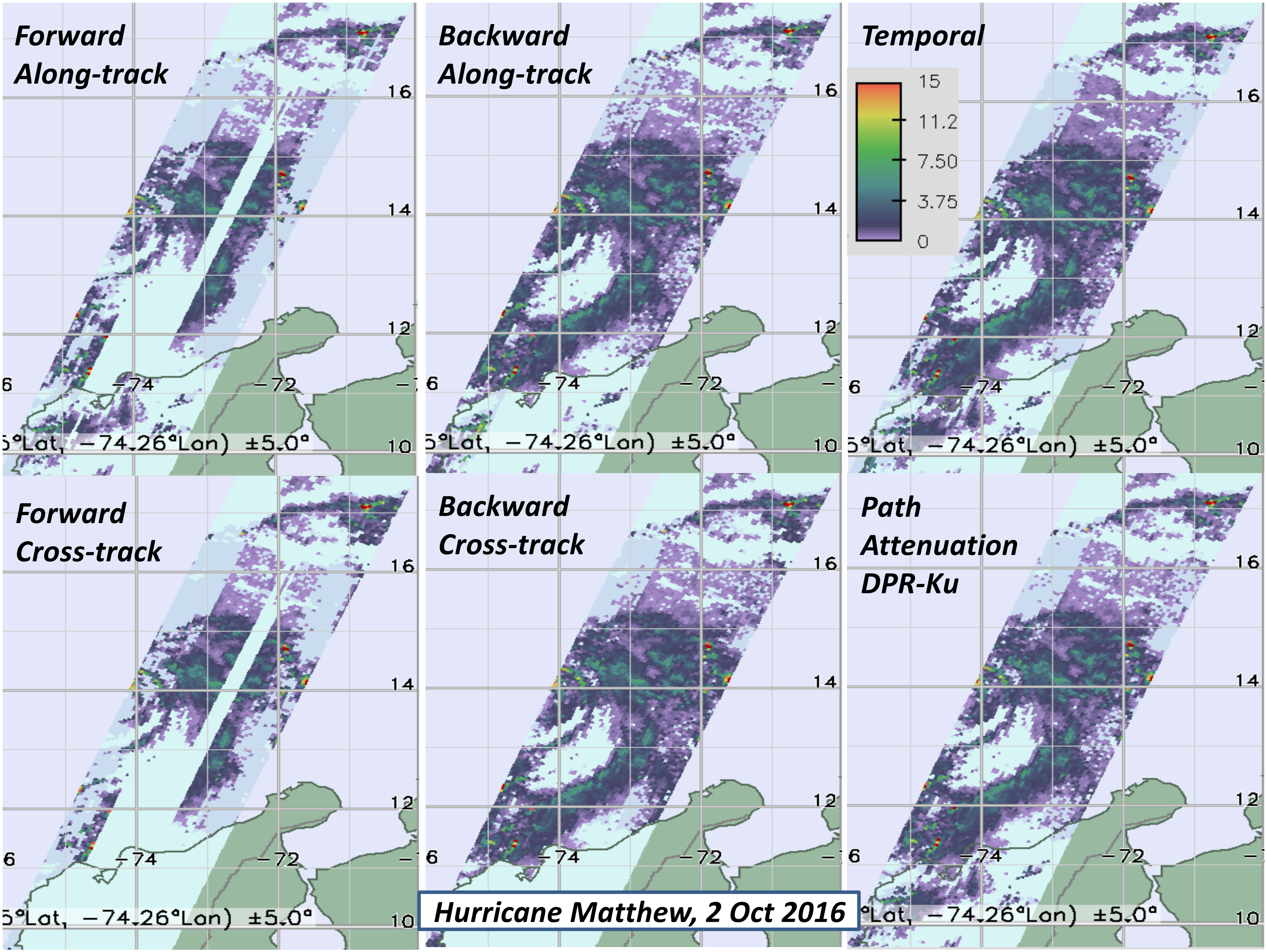


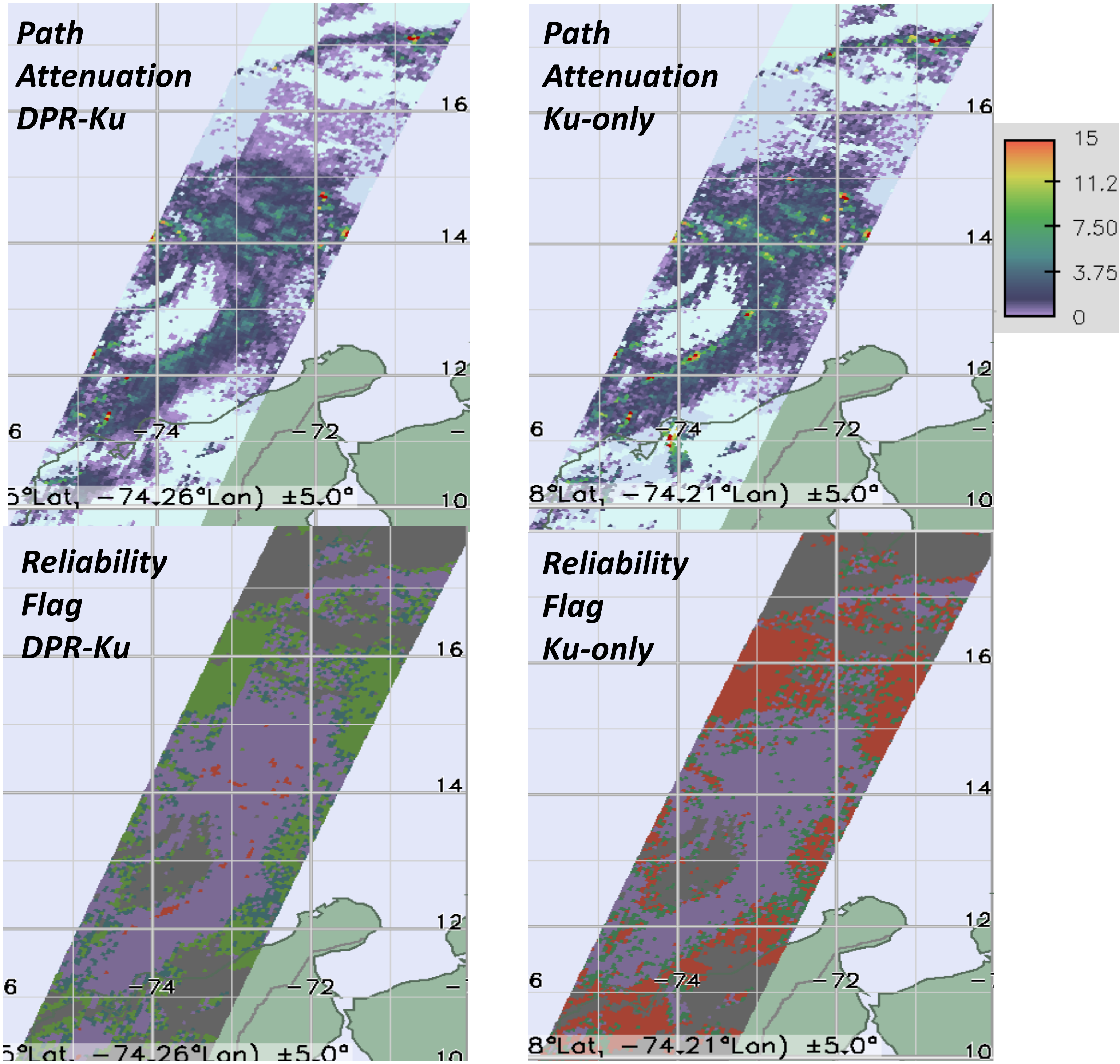
σ^0(Ku)



σ^0(Ka)

Hurricane Matthew, 2 Oct 2016


Forward Along-track
Backward Along-track
Temporal
15
11.2
7.50
3.75
0
Forward Cross-track
Backward Cross-track
Path Attenuation DPR-Ku
16
14
12
10
−74
−72
−74.26°Lon) ±5.0°
Hurricane Matthew, 2 Oct 2016



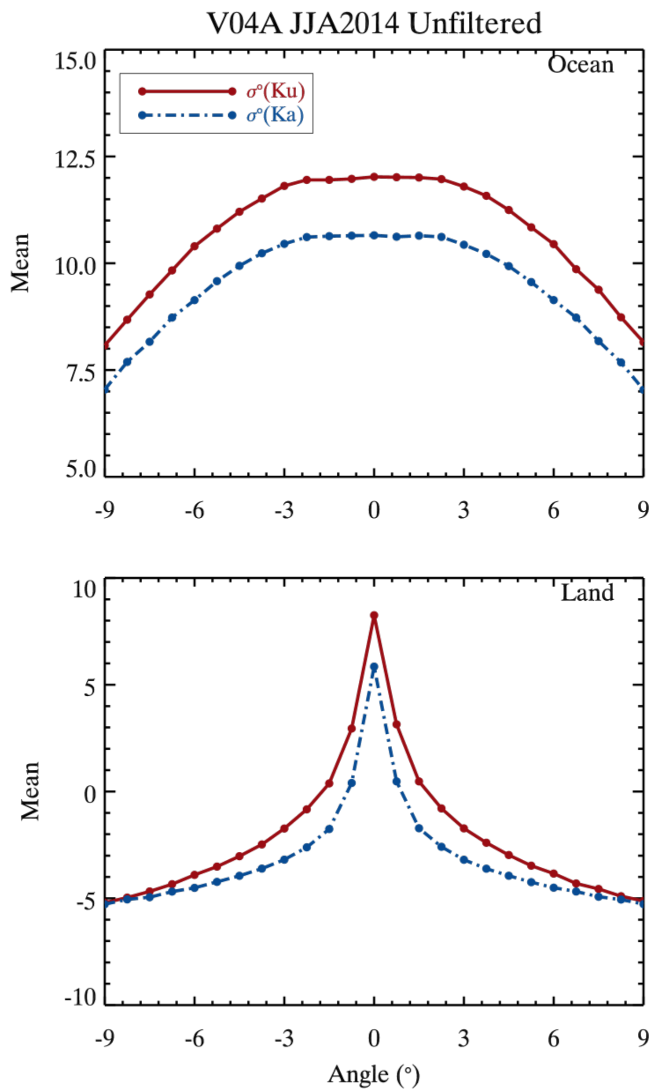
Path
Attenuation
DPR-Ku
Path
Attenuation
Ku-only
15
11.2
7.50
3.75
0
Reliability
Flag
DPR-Ku
Reliability
Flag
Ku-only

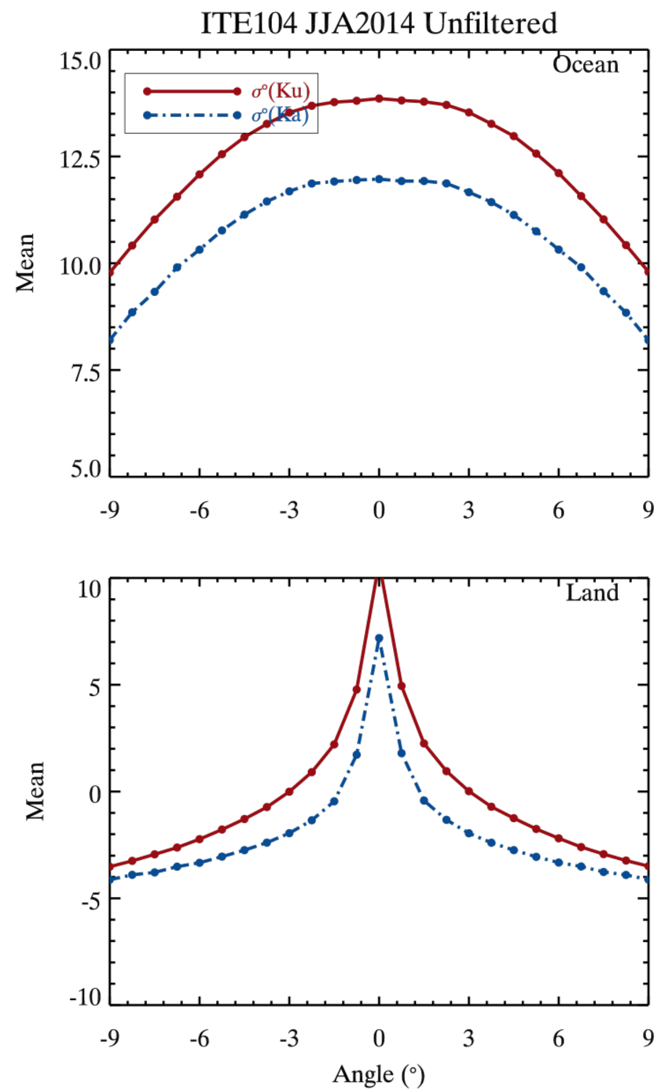
Status of Algorithm

- A number of parameters used to compute σ^0 have changed
  - Redo temporal reference look-up tables
  - Compare path attenuations from V4 and V5
- Modify code & reference data for 5 surface types (ocean/land/coast/sea-ice/snow)
- Optional use of corrections for saturated Ku-band σ^0 data

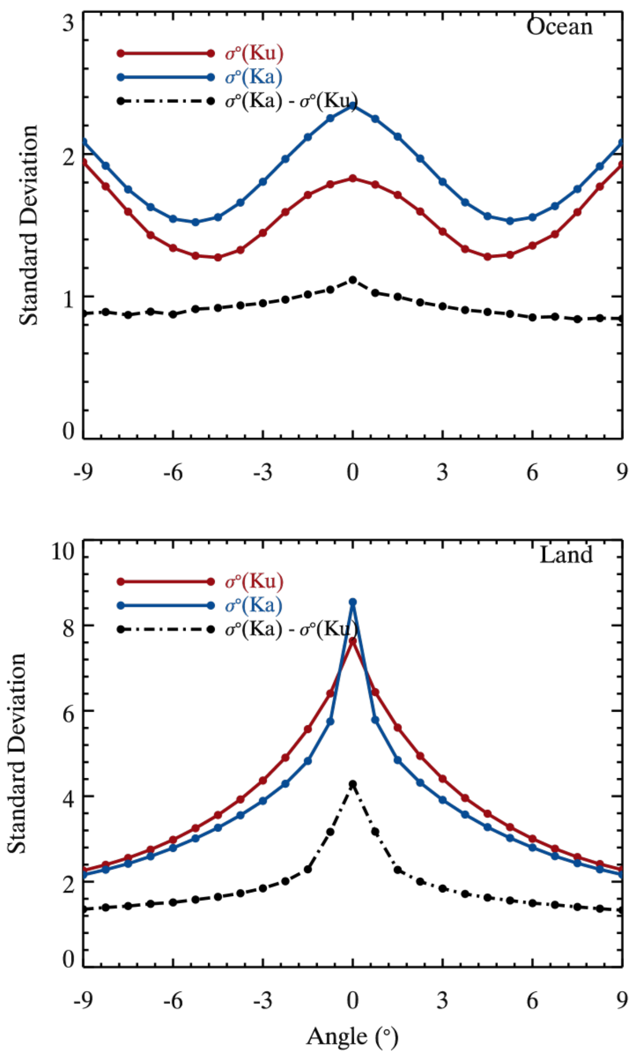
V4

V5

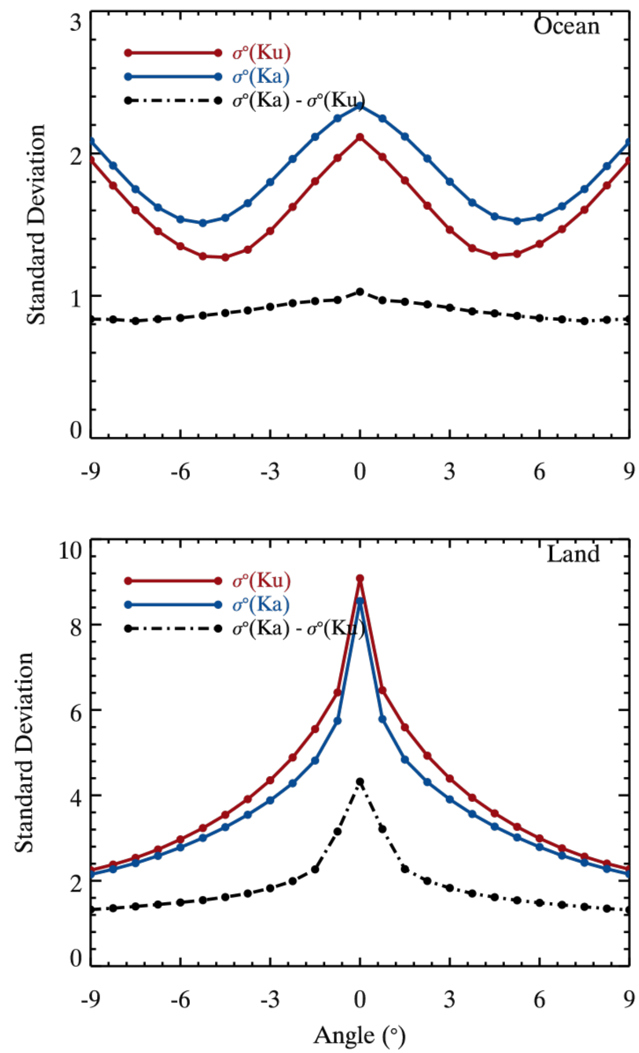

V04A JJA2014 Unfiltered
Ocean
σ°(Ku)
σ°(Ka)
Mean
Land
Mean
Angle (°)


ITE104 JJA2014 Unfiltered
Ocean
σ°(Ku)
σ°(Ka)
Mean
Land
Mean
Angle (°)

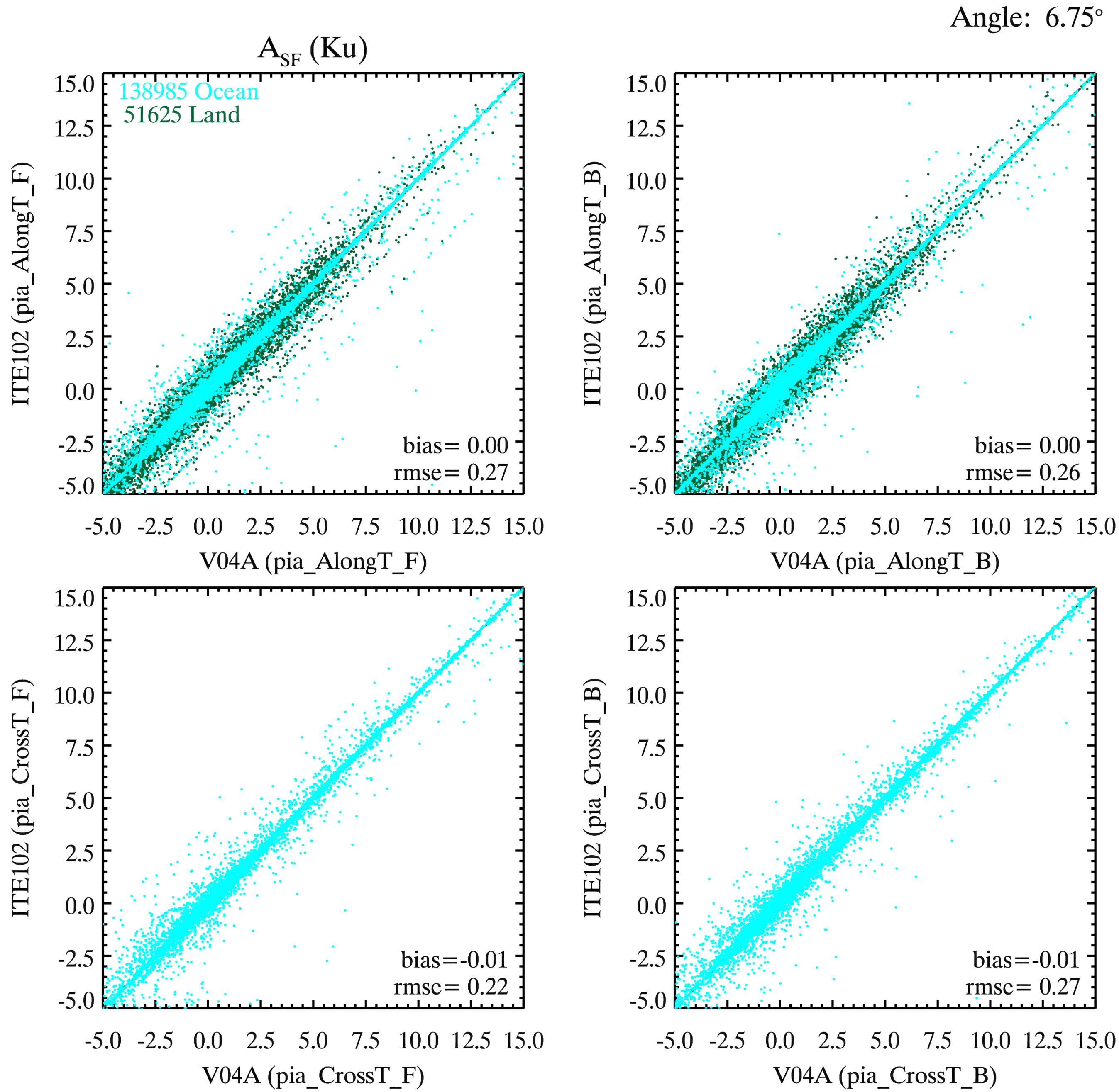
V4


Ocean
σ°(Ku)
σ°(Ka)
σ°(Ka) - σ°(Ku)
Standard Deviation
Land
σ°(Ku)
σ°(Ka)
σ°(Ka) - σ°(Ku)
Standard Deviation
Angle (°)

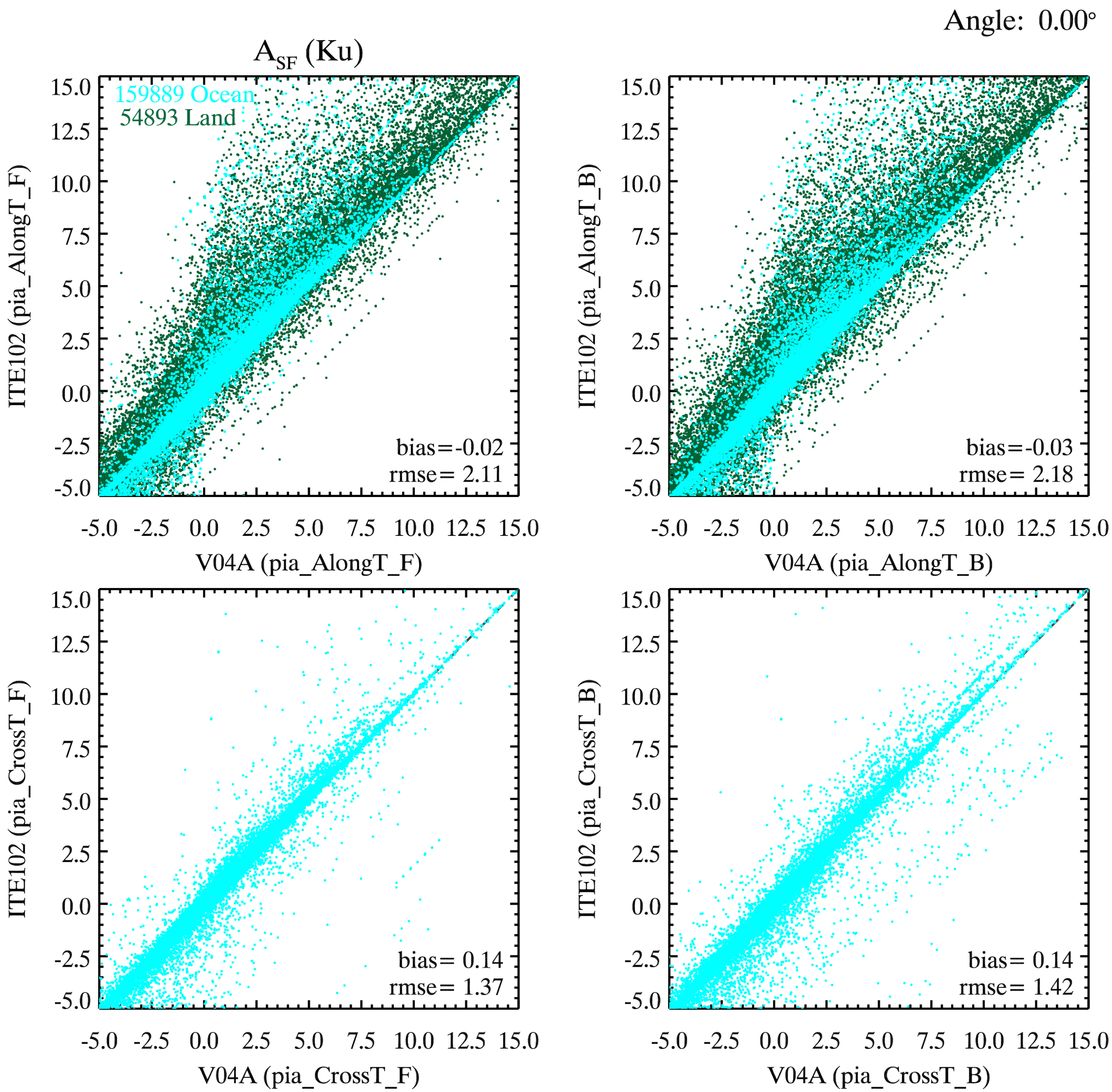
V5


Ocean
σ°(Ku)
σ°(Ka)
σ°(Ka) - σ°(Ku)
Standard Deviation
Land
σ°(Ku)
σ°(Ka)
σ°(Ka) - σ°(Ku)
Standard Deviation
Angle (°)

Path Attenuations: V5 (ordinate) vs V4 (abscissa) [Ku-band]



Path Attenuations: V5 (ordinate) vs V4 (abscissa) [Ku-band]



How can we improve the estimates of path attenuation?

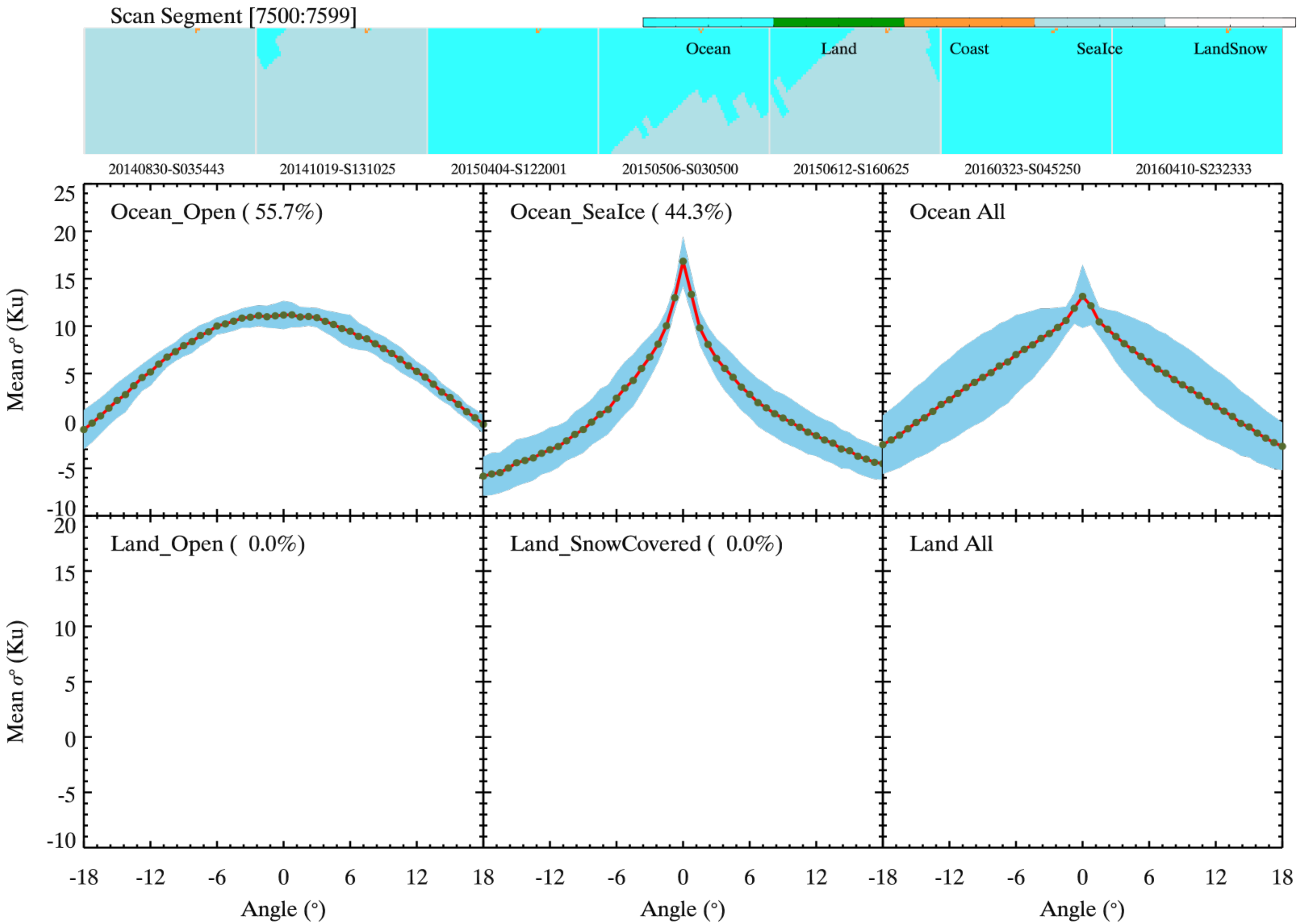
- Reduce the standard deviation of the rain-free σ^0 reference data
  - Address the under-sampling problem at near-nadir incidence
  - Reduce the variability of the temporal reference data
  - Add new surface types: sea-ice, snow-covered land
- Reduce the errors caused by non-uniform beam-filling

Sea-Ice & Snow-covered Land

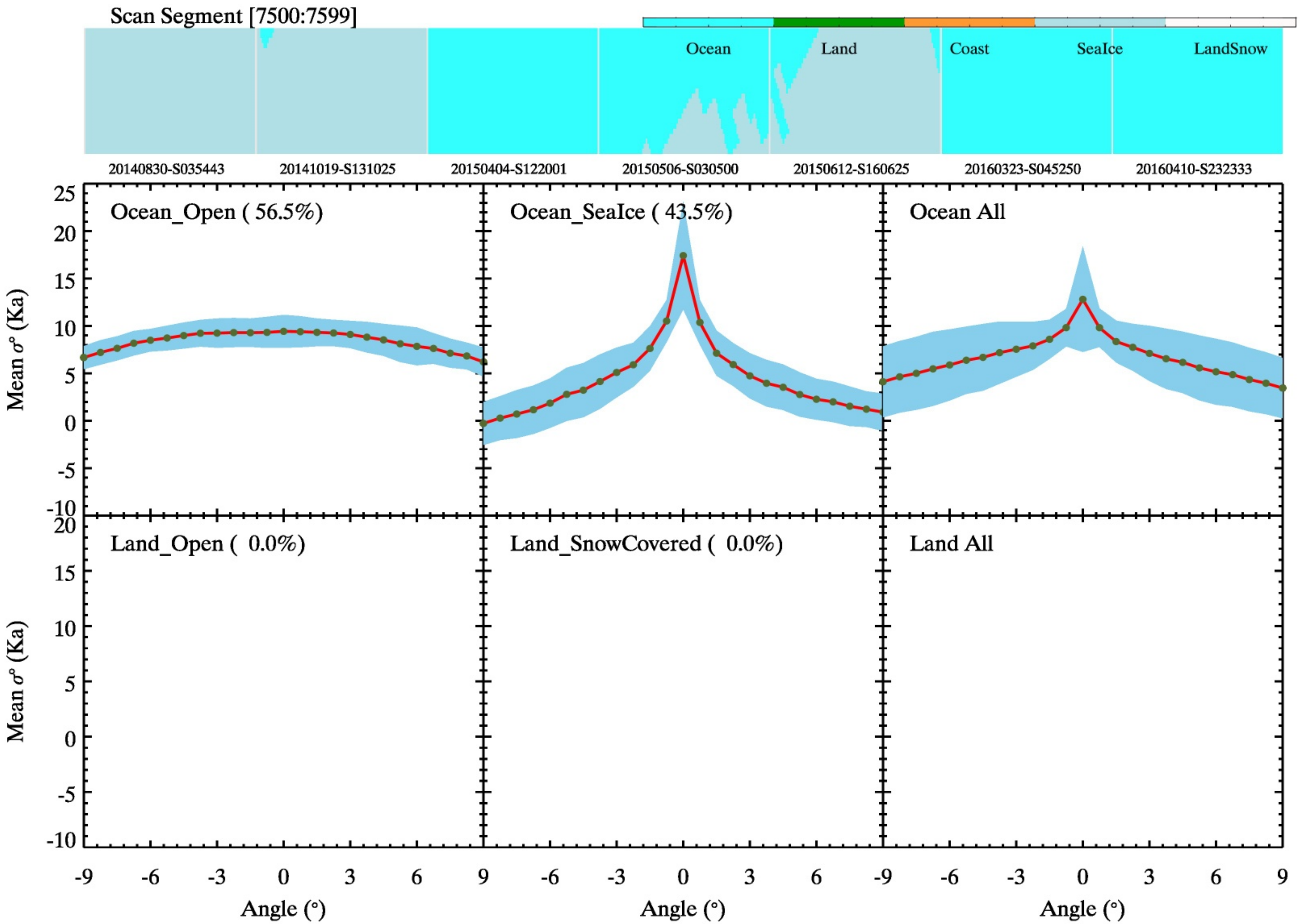
- Motivation
  - The variance of σ^0 at high latitudes can be reduced substantially if open ocean and sea-ice cases are separated
    - The mean rain-free σ^0 for the combined data generally will be incorrect for both categories
  - Evidence points to some reduction in variance if land & snow-covered land are also distinguished

Orbit Clustering

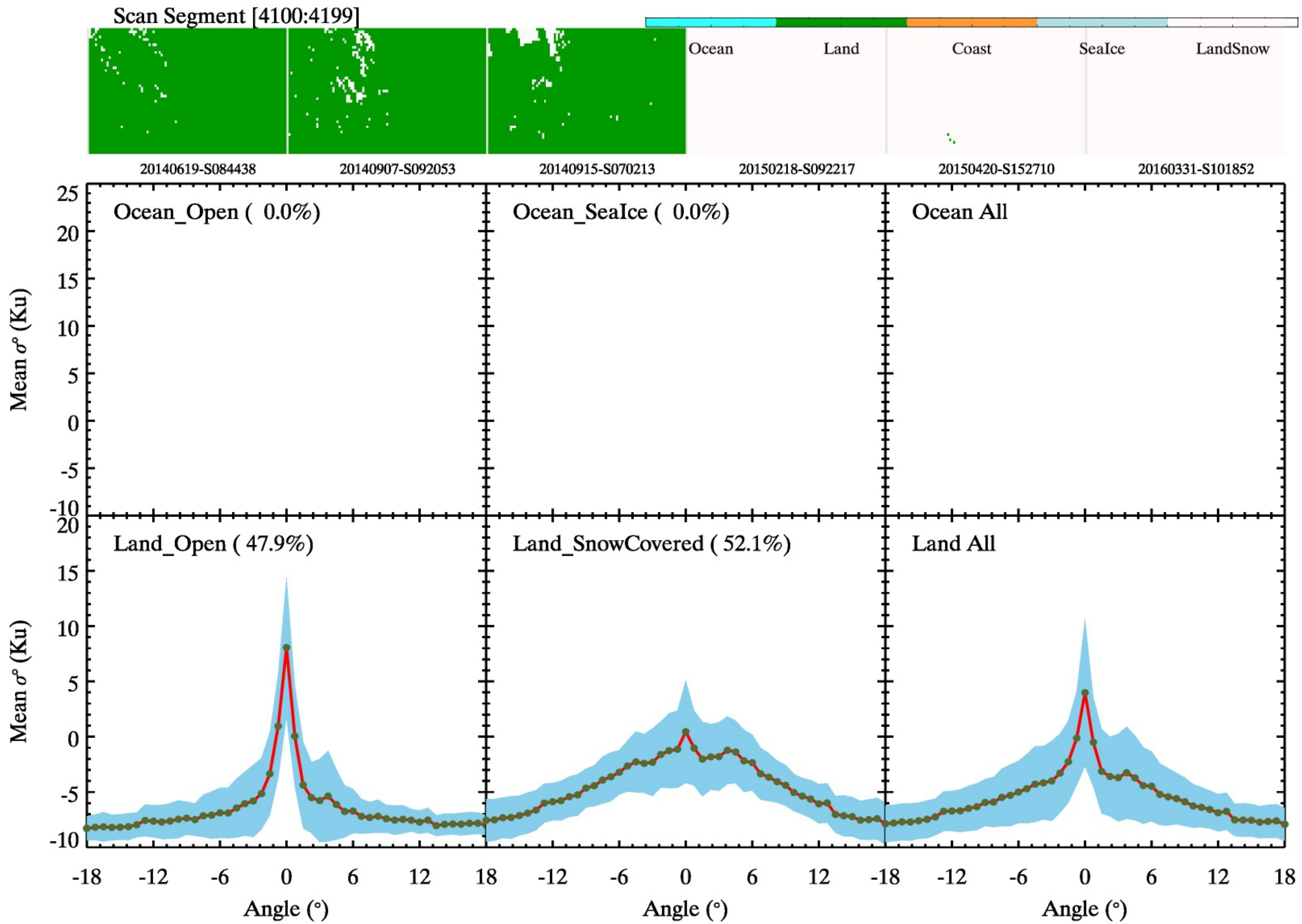
- Insight into the influence of surface type (and accuracy of temporal reference) and can be obtained by looking at tight clusters of orbits
  - Search for sets of orbits (7) with nearly identical trajectories (deviation less than 1 FOV)
  - Data also can be used to test the performance of the temporal reference PIA estimates under ideal conditions (minimum spatial variation)

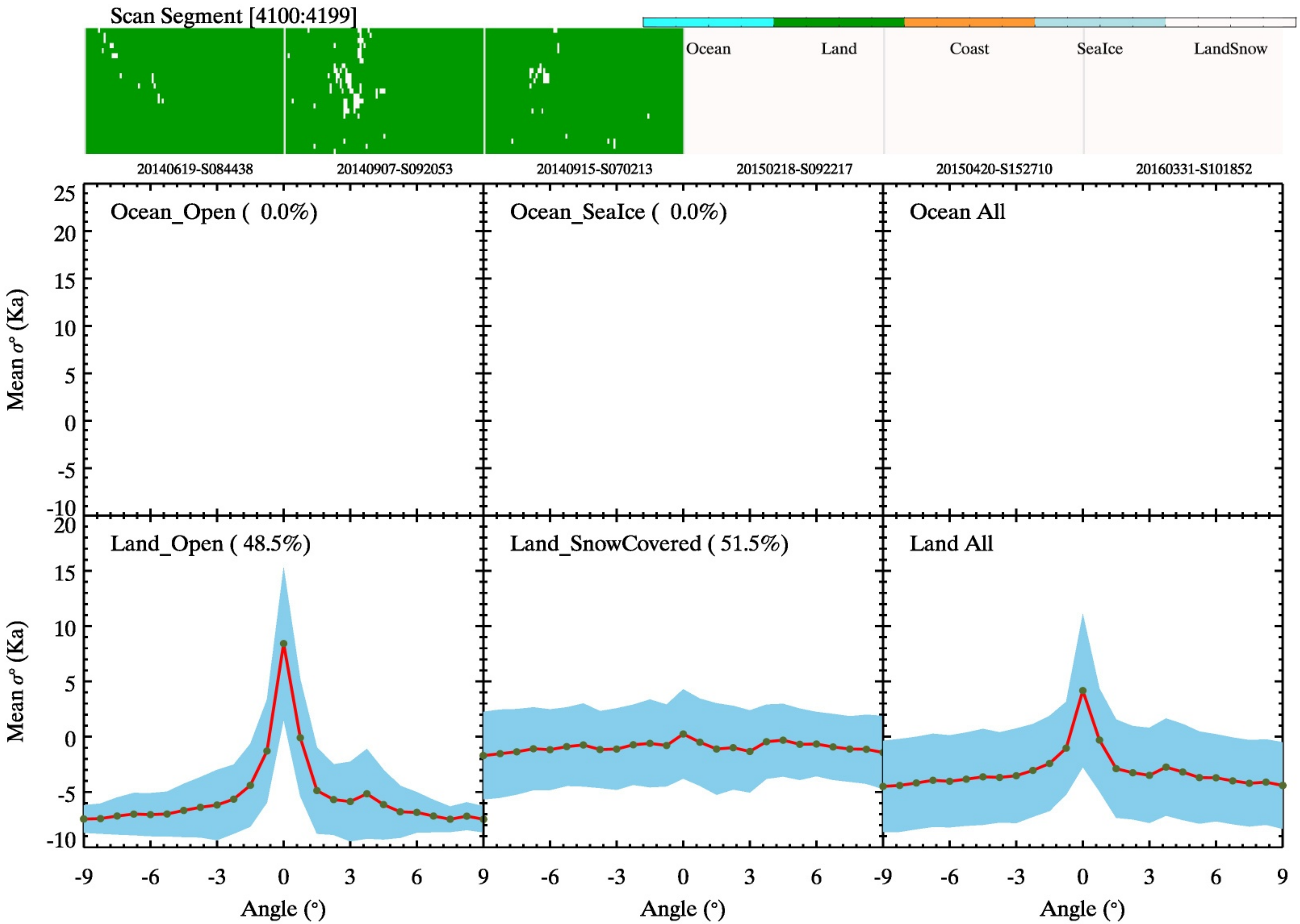


Scan Segment [7500:7599]
Ocean
Land
Coast
SeaIce
LandSnow
20140830-S035443
20141019-S131025
20150404-S122001
20150506-S030500
20150612-S160625
20160323-S045250
20160410-S232333
Ocean_Open (55.7%)
Ocean_SeaIce (44.3%)
Ocean All
Land_Open (0.0%)
Land_SnowCovered (0.0%)
Land All
Mean σ° (Ku)
Angle (°)



Scan Segment [7500:7599]
Ocean
Land
Coast
SeaIce
LandSnow
20140830-S035443
20141019-S131025
20150404-S122001
20150506-S030500
20150612-S160625
20160323-S045250
20160410-S232333
Ocean_Open (56.5%)
Ocean_SeaIce (43.5%)
Ocean All
Land_Open (0.0%)
Land_SnowCovered (0.0%)
Land All
Mean σ° (Ka)
Angle (°)

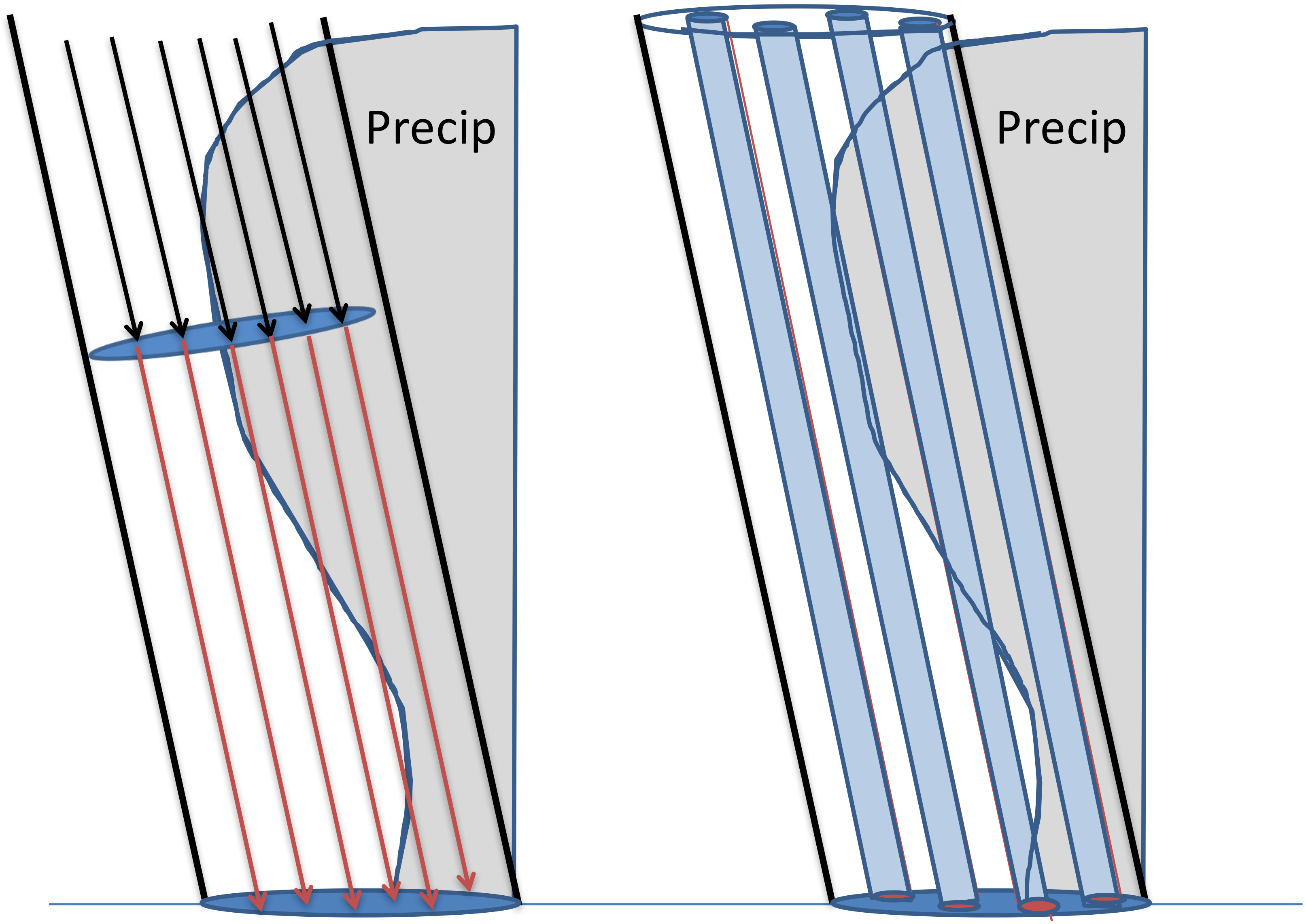

Scan Segment [4100:4199]
Ocean
Land
Coast
SeaIce
LandSnow
20140619-S084438
20140907-S092053
20140915-S070213
20150218-S092217
20150420-S152710
20160331-S101852
Ocean_Open (0.0%)
Ocean_SeaIce (0.0%)
Ocean All
Land_Open (47.9%)
Land_SnowCovered (52.1%)
Land All
Mean σ° (Ku)
Angle (°)



Scan Segment [4100:4199]
Ocean
Land
Coast
SeaIce
LandSnow
20140619-S084438
20140907-S092053
20140915-S070213
20150218-S092217
20150420-S152710
20160331-S101852
Ocean_Open (0.0%)
Ocean_SeaIce (0.0%)
Ocean All
Land_Open (48.5%)
Land_SnowCovered (51.5%)
Land All
Mean σ° (Ka)
Angle (°)

NUBF Mitigation

- Motivation
  - Attenuation & NUBF are closely linked
  - Attenuation effects exacerbate the NUBF problem
  - As such, the problem is more severe at Ka-band than at Ku-band
  - If we had higher resolution data, the retrieval errors would decrease
- Approach
  - Using ancillary data (in adjacent/interleaved/range-sampled FOV's), interpolate both PIA & Z_m to higher resolution columns
  - Normalize the interpolated fields to satisfy the initial conditions
  - In this higher resolution space, solve for hi-res Z(x,y,z) over the multiple columns using traditional methods


Precip
Precip

NUBF Mitigation (some eq's)

$$A(\theta) = 2\int_0^{r_s} k(\theta, s)ds \approx \langle P_s(No\,Rain, \theta)\rangle - P_s(Rain, \theta)$$

$$A(\theta) = -q^{-1}\log\left[\frac{\iint G^2(x,y)\sigma_R^0(x,y)\exp[-2q\int_0^{r_s} k(s;x,y))ds]\,dxdy}{\iint G^2(x,y)\sigma_{NR}^0(x,y)dxdy}\right]$$

$$let\quad g = G^2 / \iint G^2(x,y)dxdy; \qquad a(\theta;x,y) = 2\int_0^{r_s} k(\theta,x,y;s))\,ds$$

$$assume\ \sigma_{NR}^0 = \sigma_R^0; \quad (note\ that\ q = 0.2303)$$

$$A(\theta) = -q^{-1}\log\Big[\iint_{FOV} g(x,y)\exp(-qa(\theta;x,y))dxdy\Big] \qquad (1)$$

$$if\ beam\ is\ uniformly\ filled,\ A(\theta) = a(\theta)$$

NUBF Mitigation

Similarly

$$Z_{m,dB}(h) = q^{-1}\log[\iint_{FOV} g(x,y)z_m(x,y;h)dxdy] \qquad (2)$$

Note that near the surface, the hi-res fields are related by

$$z(x,y) = z_m(x,y)\exp(-qa(x,y))$$

where $z(x,y)$ *is the hi-res, attenuation-corrected reflectivity factor*

NUBF Mitigation

Replace high-res fields with the interpolated fields along with adjustment factors

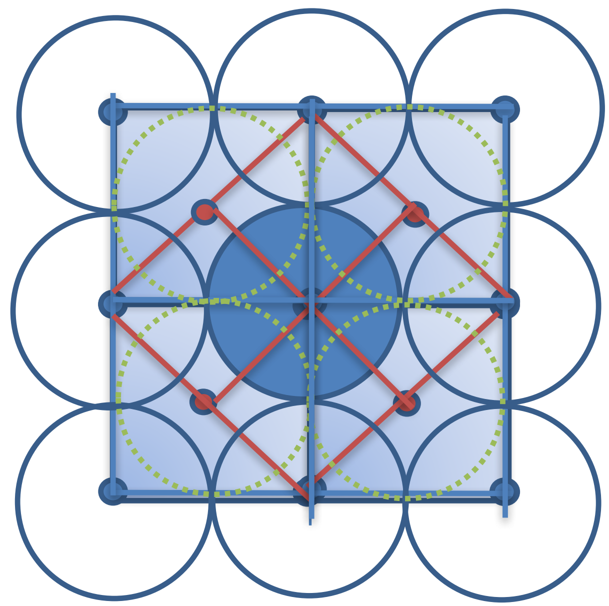
$$a(x,y) \rightarrow \tilde{a}(x,y) + \delta_a$$

$$z_m(x,y) \rightarrow \delta_{z_m} \tilde{z}_m(x,y)$$

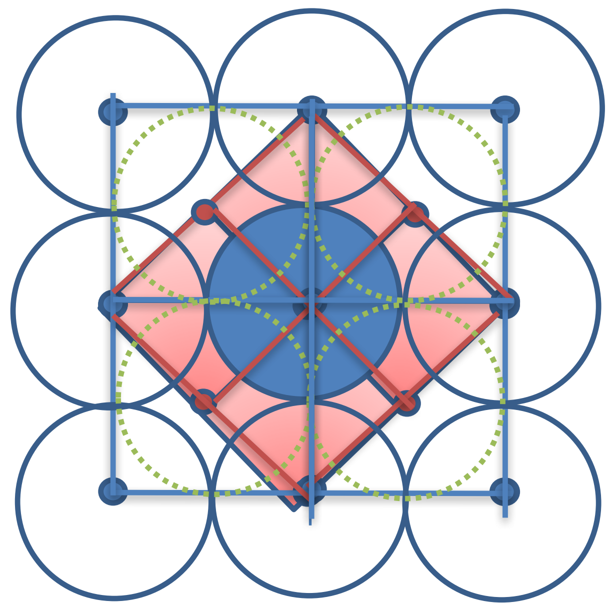
$$adjust\,\delta_a\ and\ \delta_{z_m}\ so\,that\,(1)\,and\,(2)\,are\,satisfied$$

Use modified interpolated fields in standard retrieval equations to get Z(x, y, z) at interpolated resolution

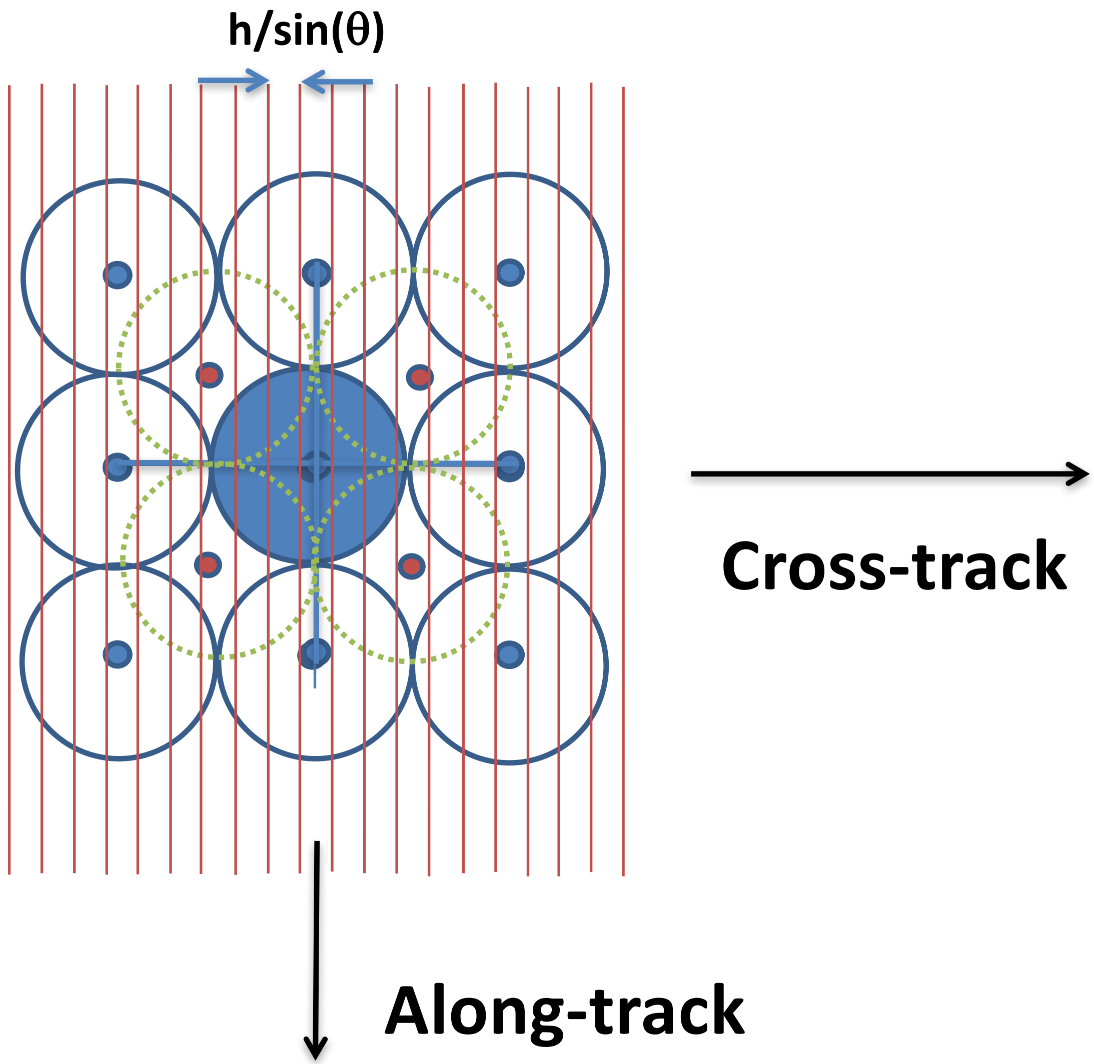
Nadir Geometry (Standard Data)



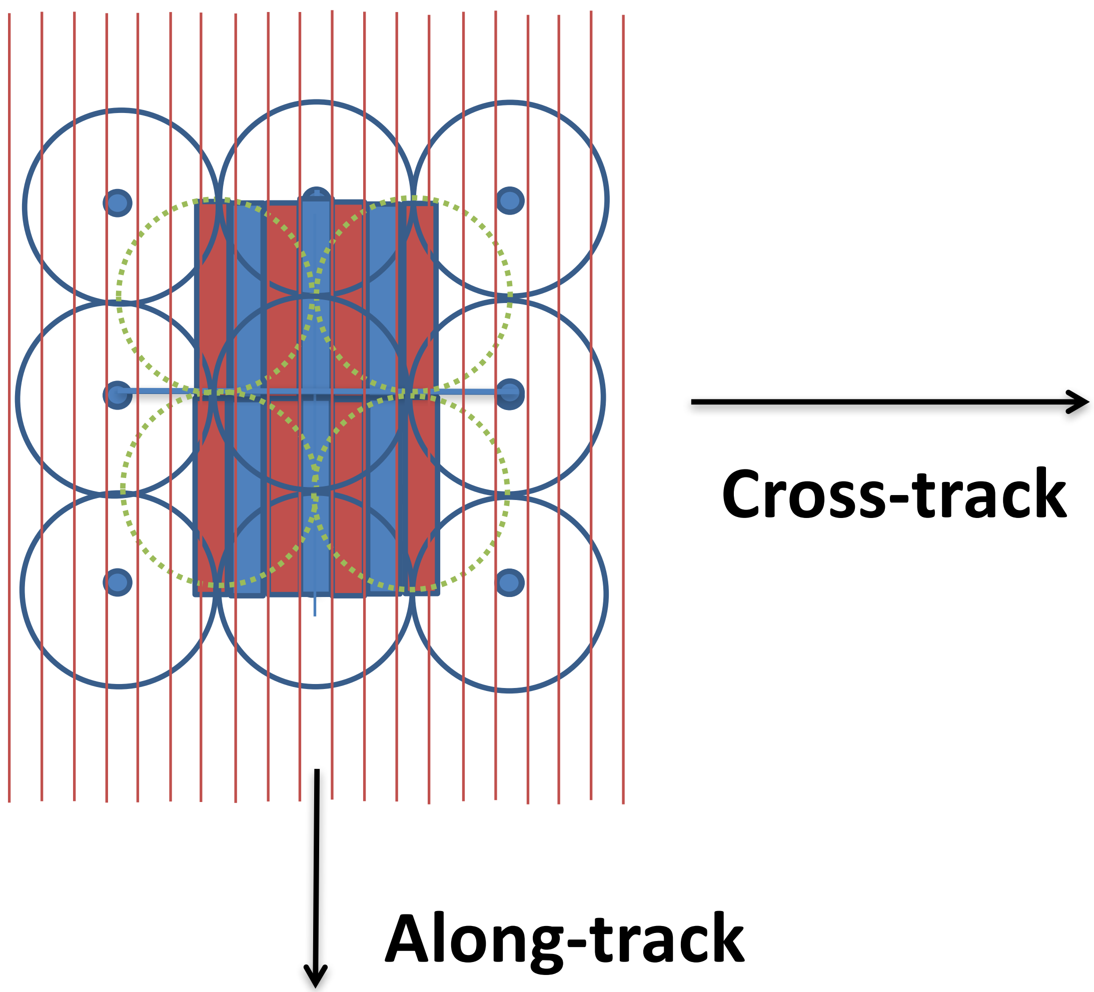
Nadir Geometry (w/ Interleaved Data)

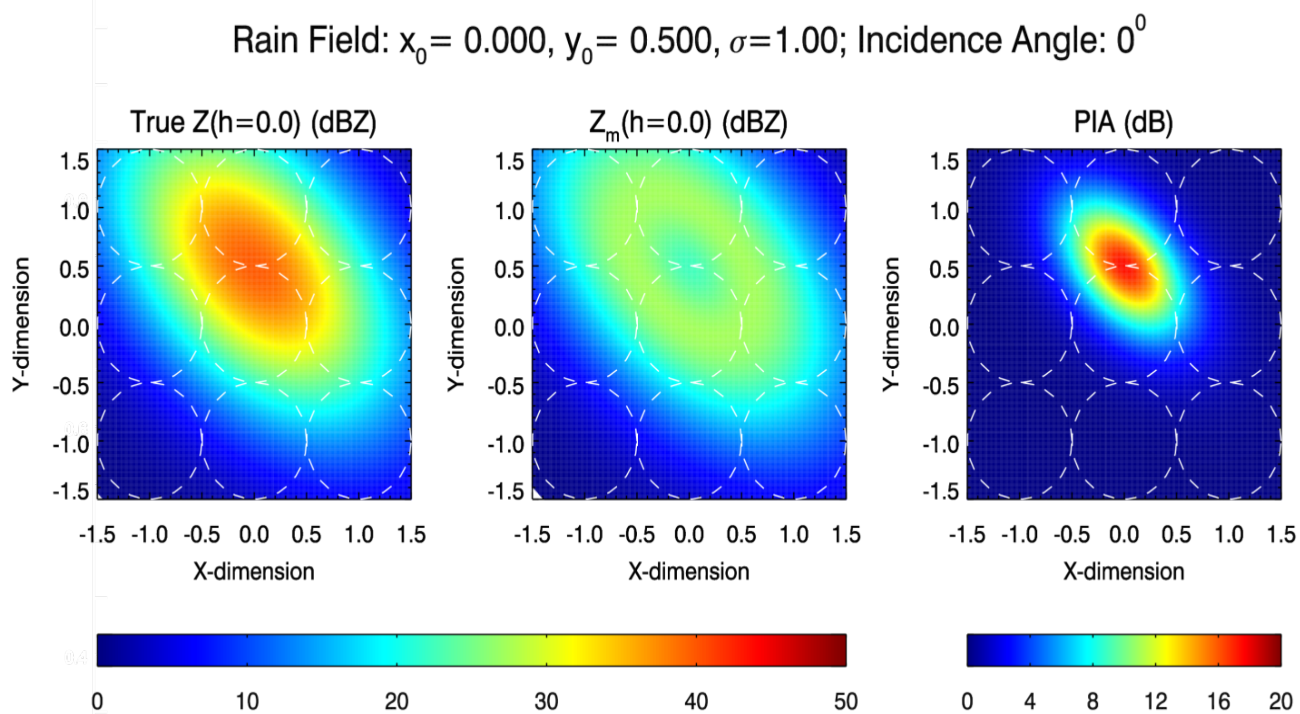


Off-Nadir Geometry with Range-Profiled PIA

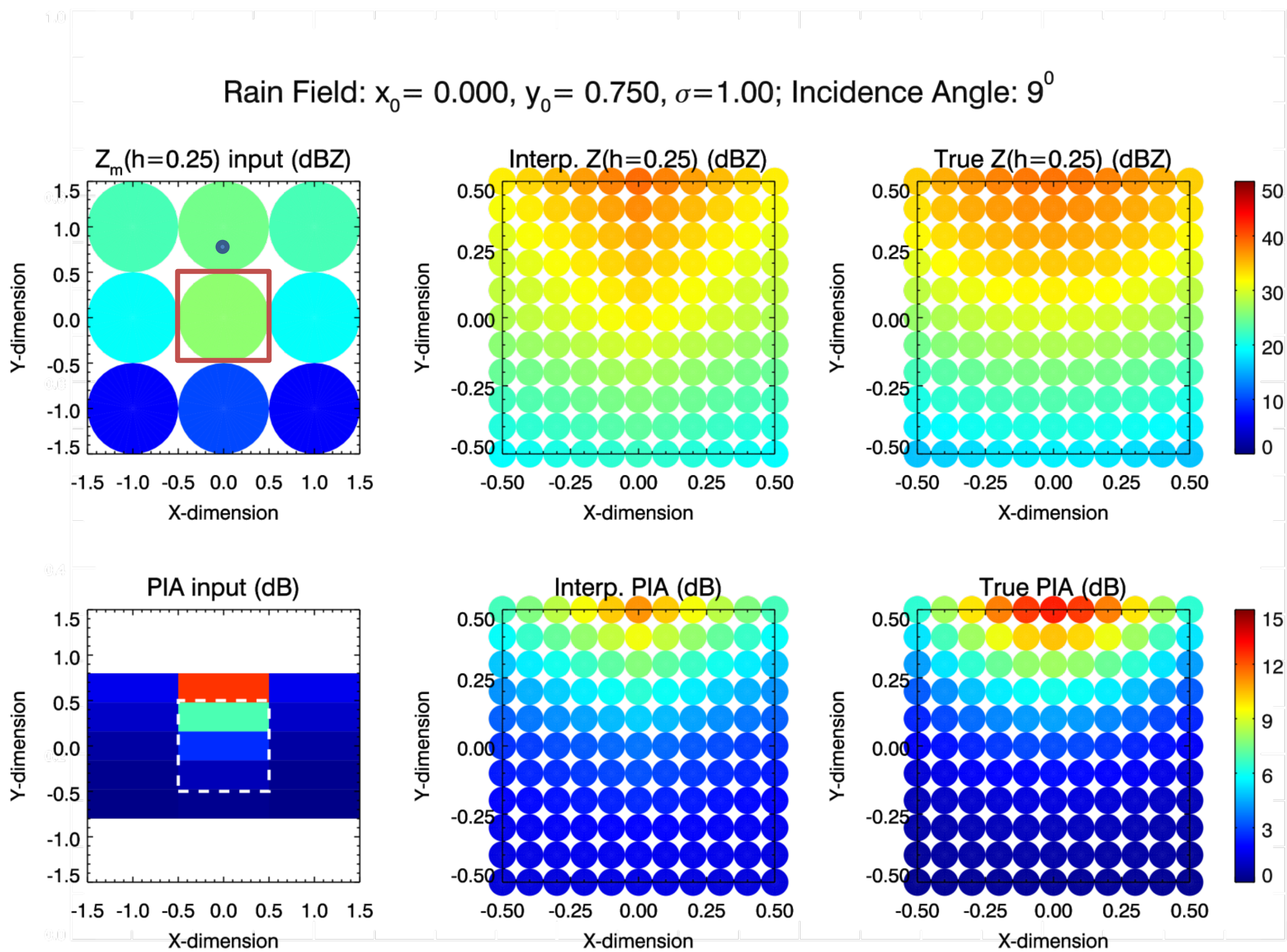


Off-Nadir Geometry with Range-Profiled PIA



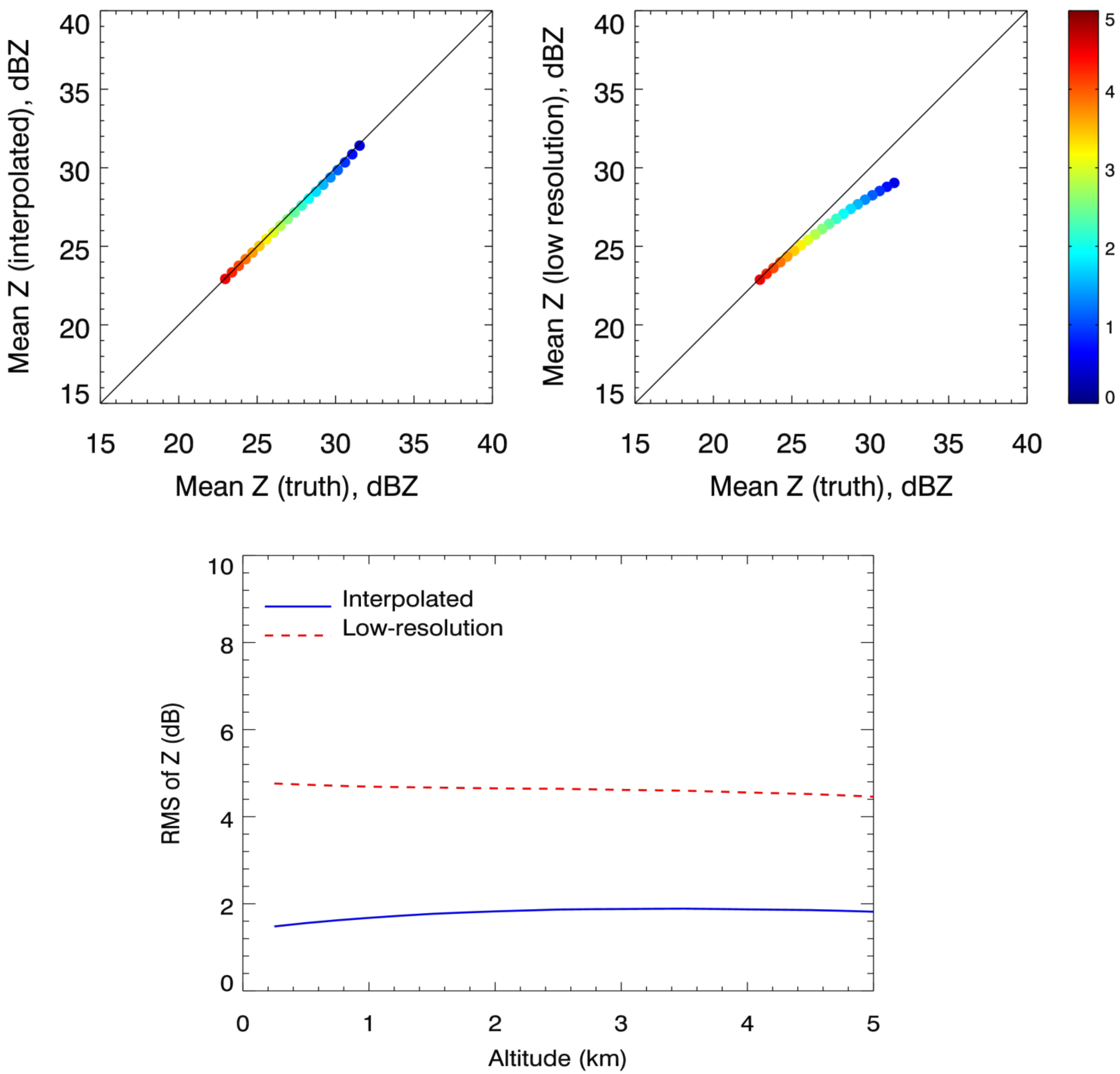


Rain Field: x_0= 0.000, y_0= 0.500, σ=1.00; Incidence Angle: 0^0
True Z(h=0.0) (dBZ)
Z_m(h=0.0) (dBZ)
PIA (dB)
Y-dimension
X-dimension
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0
10
20
30
40
50
0
4
8
12
16
20

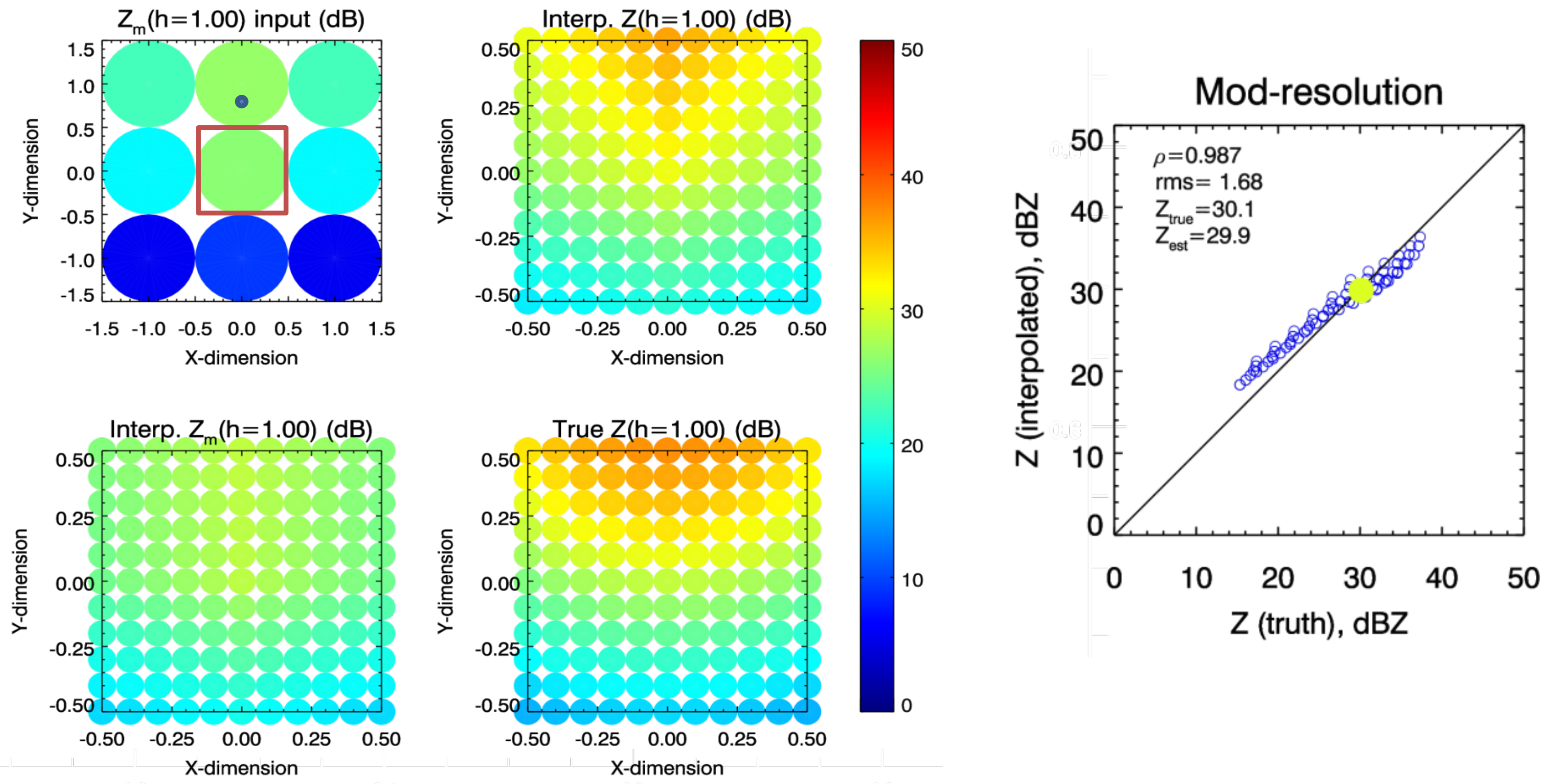


Rain Field: x_0= 0.000, y_0= 0.750, σ=1.00; Incidence Angle: 9^0
Z_m(h=0.25) input (dBZ)
Interp. Z(h=0.25) (dBZ)
True Z(h=0.25) (dBZ)
PIA input (dB)
Interp. PIA (dB)
True PIA (dB)
X-dimension
Y-dimension

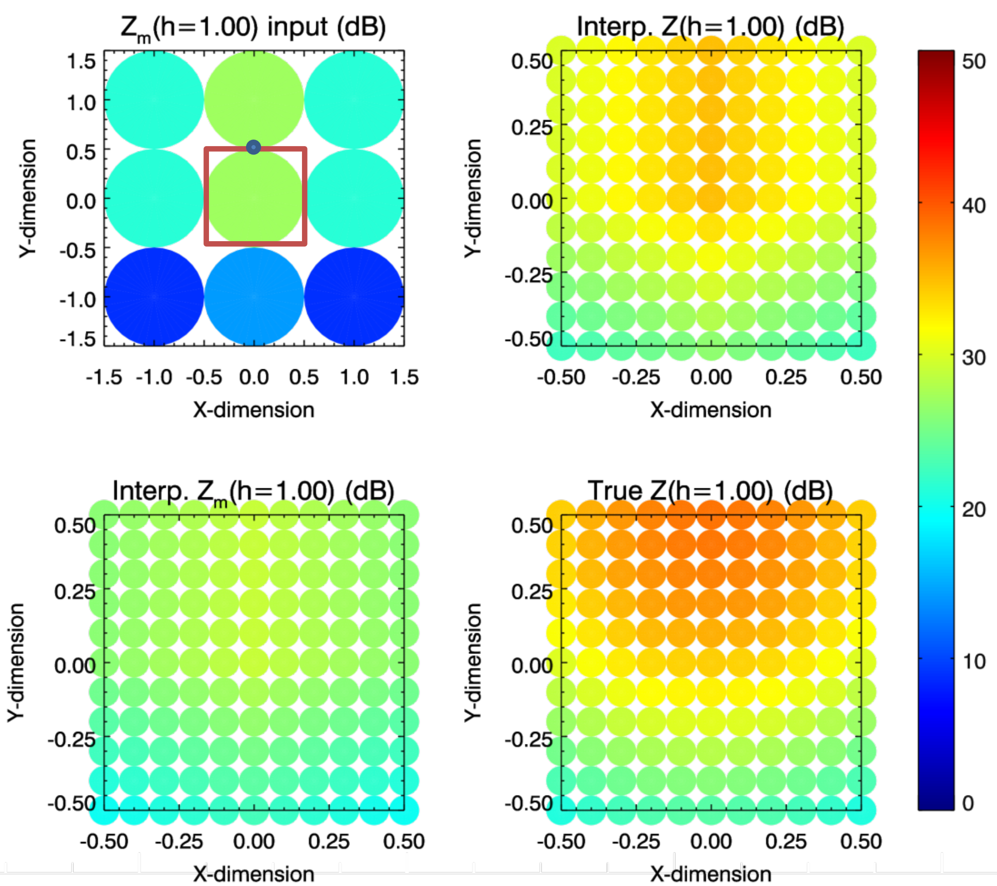
Rain Field: x_0= 0.000, y_0= 0.750, σ=1.00; Incidence Angle: 9^0

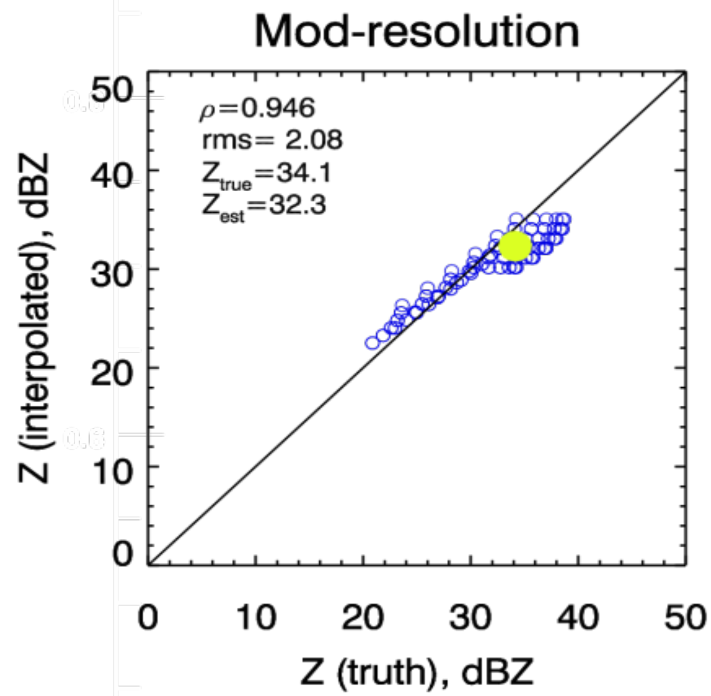


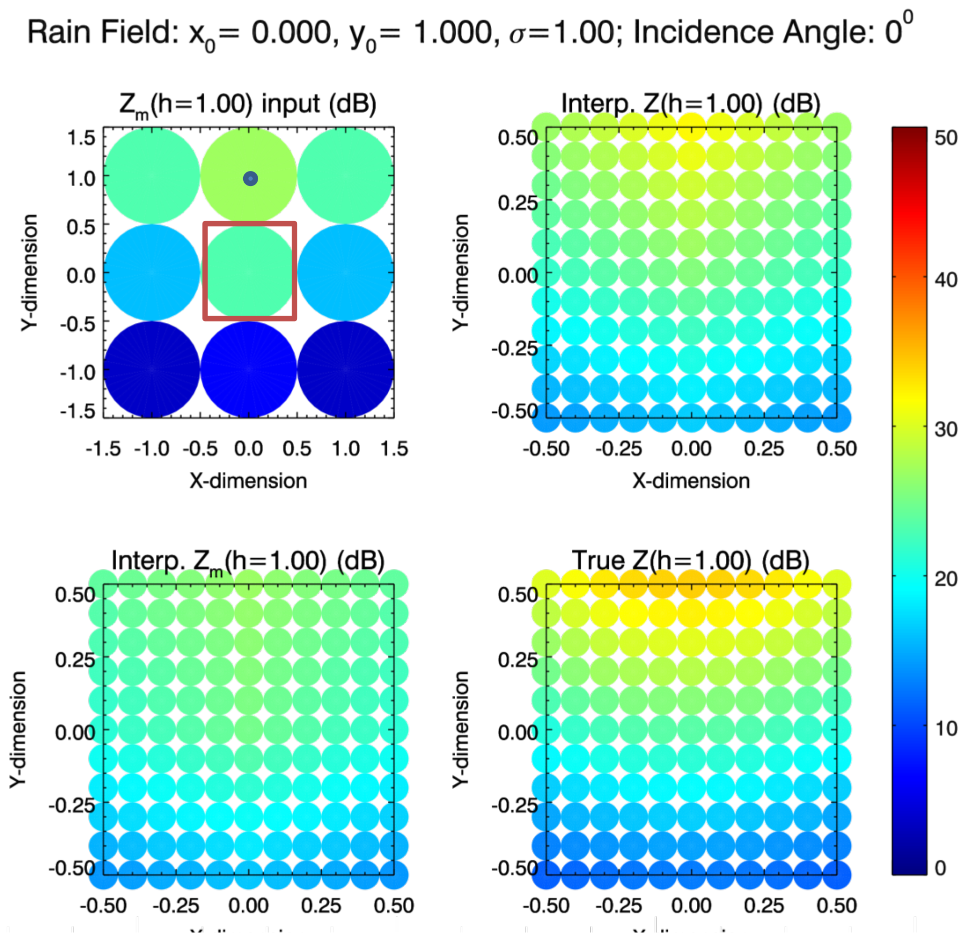
Rain Field: x_0= 0.000, y_0= 0.750, σ=1.00; Incidence Angle: 9^0



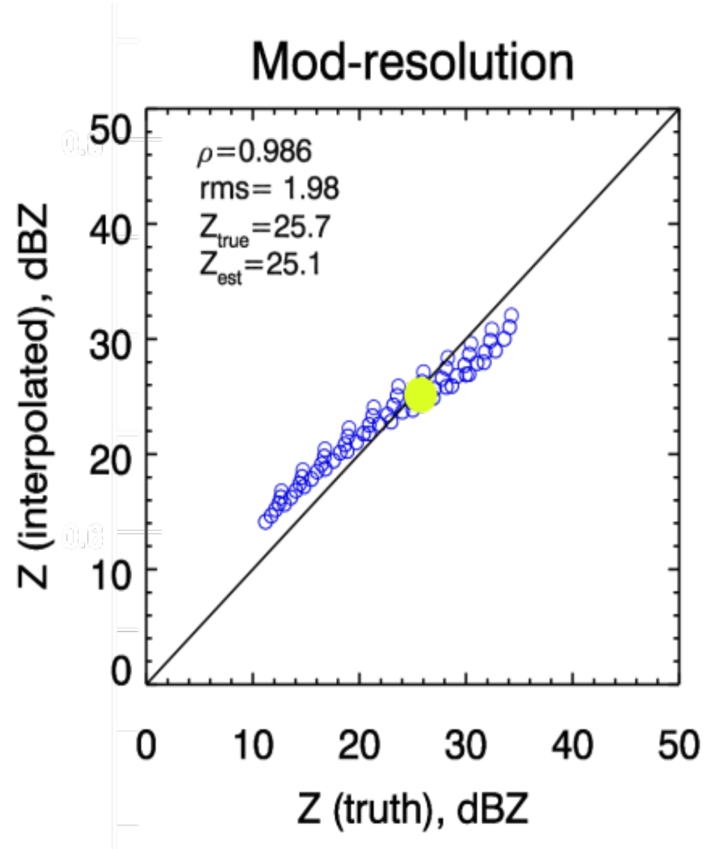
Rain Field: x_0= 0.000, y_0= 0.500, σ=1.00; Incidence Angle: 0^0







Rain Field: x_0= 0.000, y_0= 1.000, σ=1.00; Incidence Angle: 0^0
Z_m(h=1.00) input (dB)
Interp. Z(h=1.00) (dB)
Interp. Z_m(h=1.00) (dB)
True Z(h=1.00) (dB)
Y-dimension
X-dimension
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0.50
0.25
0.00
-0.25
-0.50
50
40
30
20
10
0



Mod-resolution
ρ=0.986
rms= 1.98
Z_{true}=25.7
Z_{est}=25.1
Z (interpolated), dBZ
Z (truth), dBZ
0
10
20
30
40
50

Comments

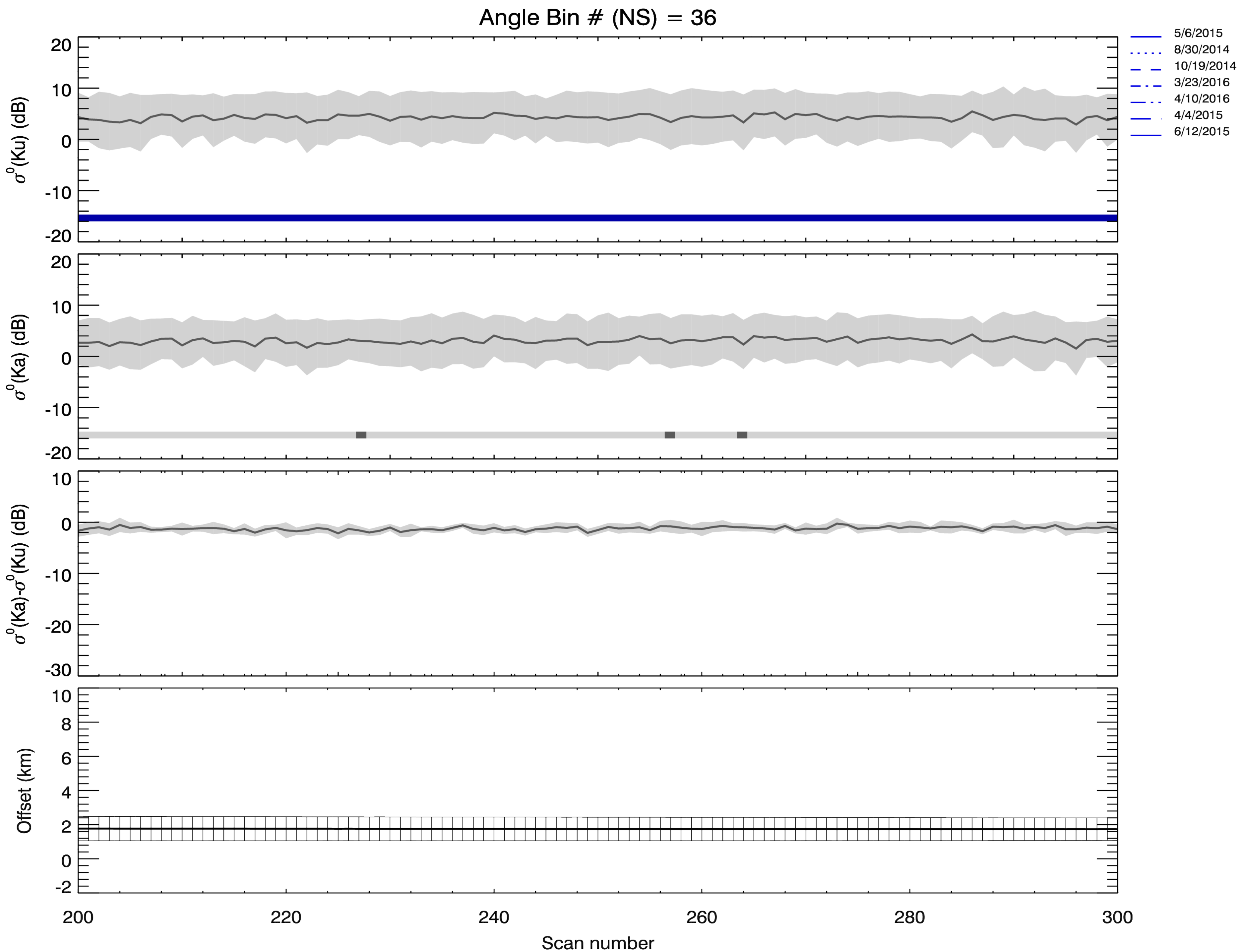
- The procedure gives some improvement, usually modest, over coarse resolution estimate
  - Greater reduction in rms error than in bias
  - Degree of improvement is non-uniform, however
- Bilinear interpolation has been used
  - Kriging & other geospatial methods might provide better results, esp when using interl. Ka-band data
- To understand the method, a simple storm model is used
  - MRMS data are being used to get a more realistic assessment of the approach

Summary

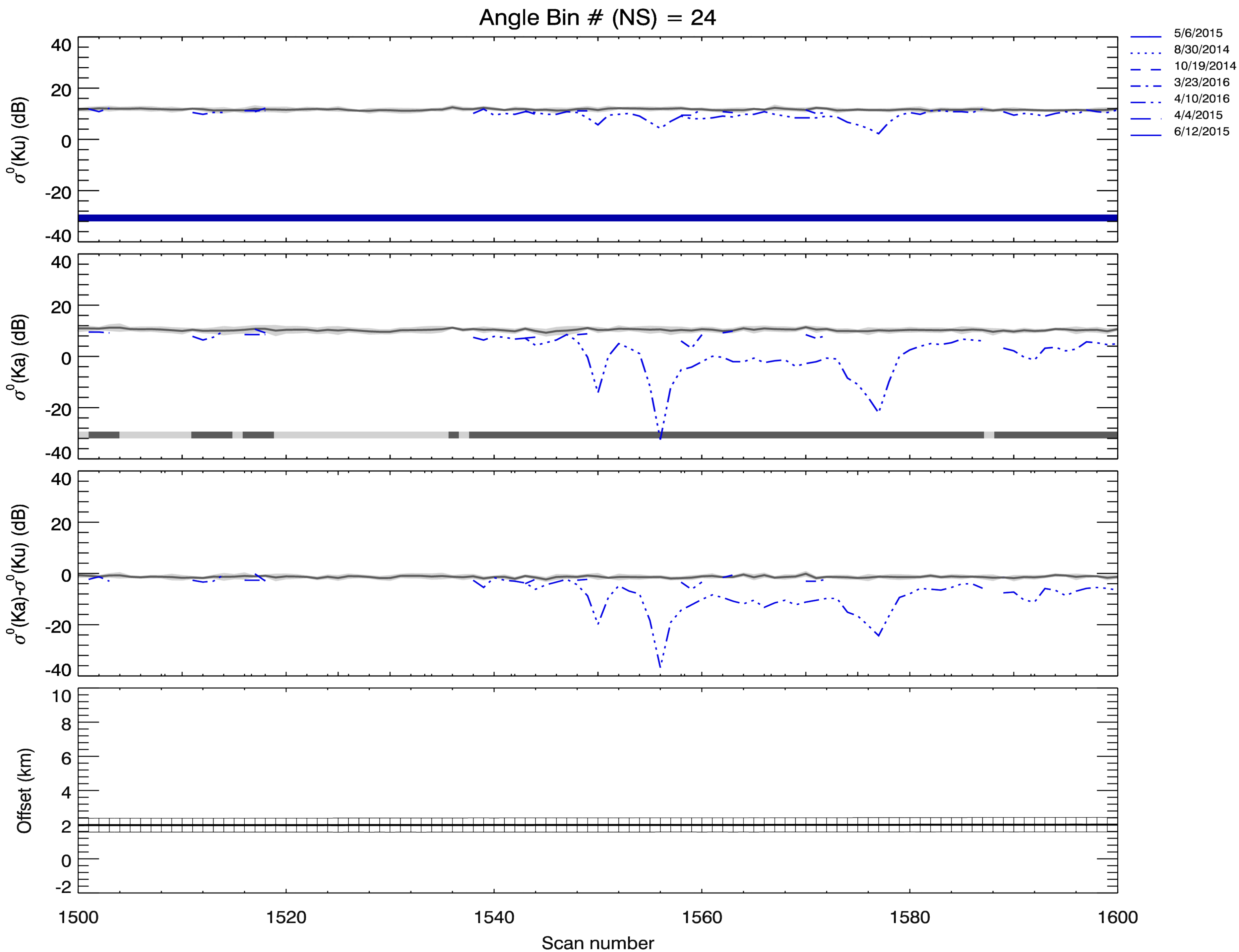
- Changes in SRT code & data bases have been made for V5
- Several improvements in the method appear to be feasible
  - Correction for under-sampling surface power at nadir
  - Variable spatial averaging of temporal reference data
  - Implementation of 5 surface categories
- An NUBF-mitigation strategy has shown some potential & will be pursued

PIA Estimates from Temporal Reference Data

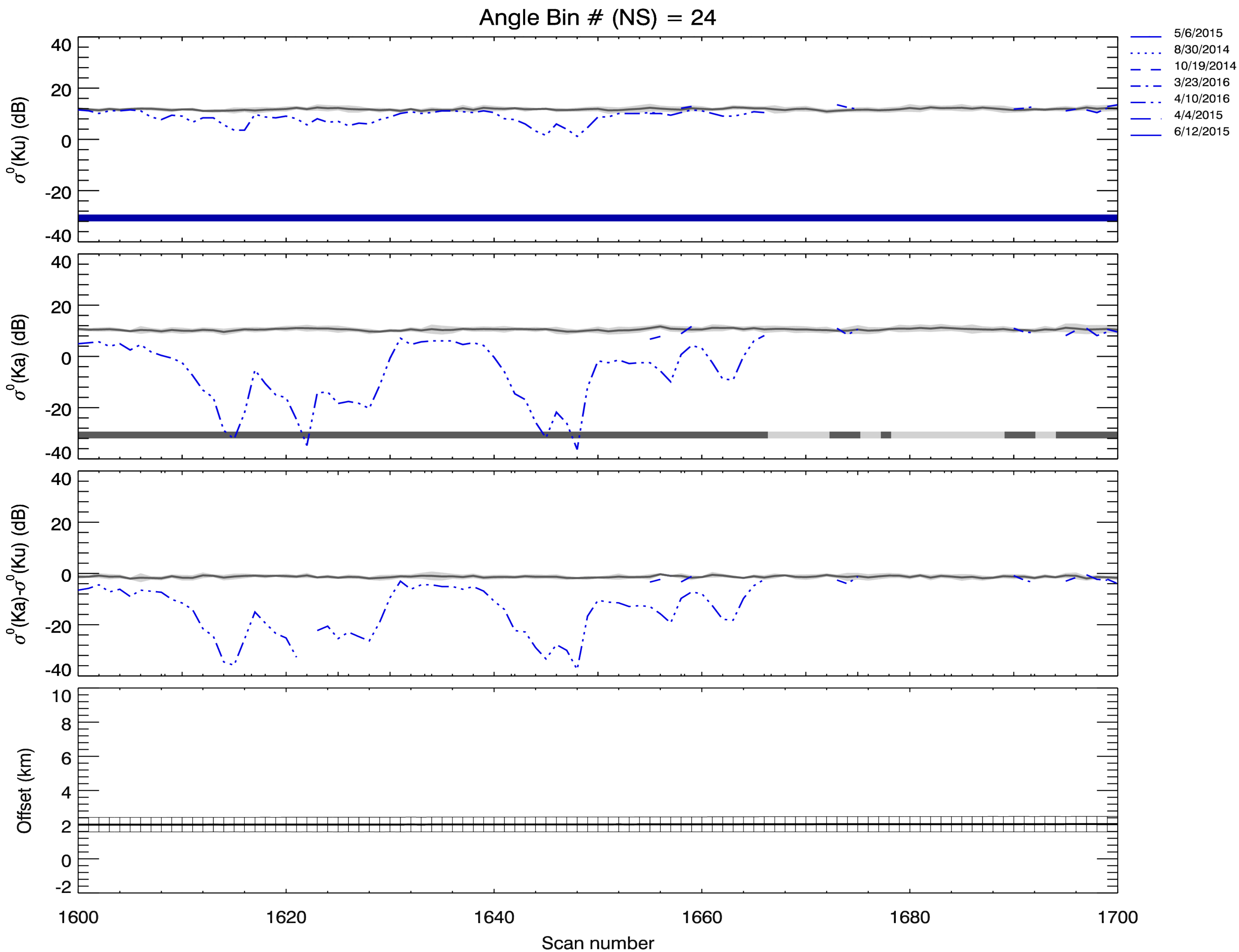
- In following slides, the mean & std dev of the rain-free σ^0 data are shown by the black line and gray area about the black line (± 1 std dev)
- Surface type is indicated by the bar in top panel
- Rain/no-rain is indicated by the bar in the 2^{nd} panel
- σ^0 data in rain are depicted by the blue lines
  - Different line types represent different orbits
- Difference between black & blue lines gives a temporal-ref estimate of the 2-way PIA
- The error assoc with the PIA is proportional to the vertical extent of the gray area

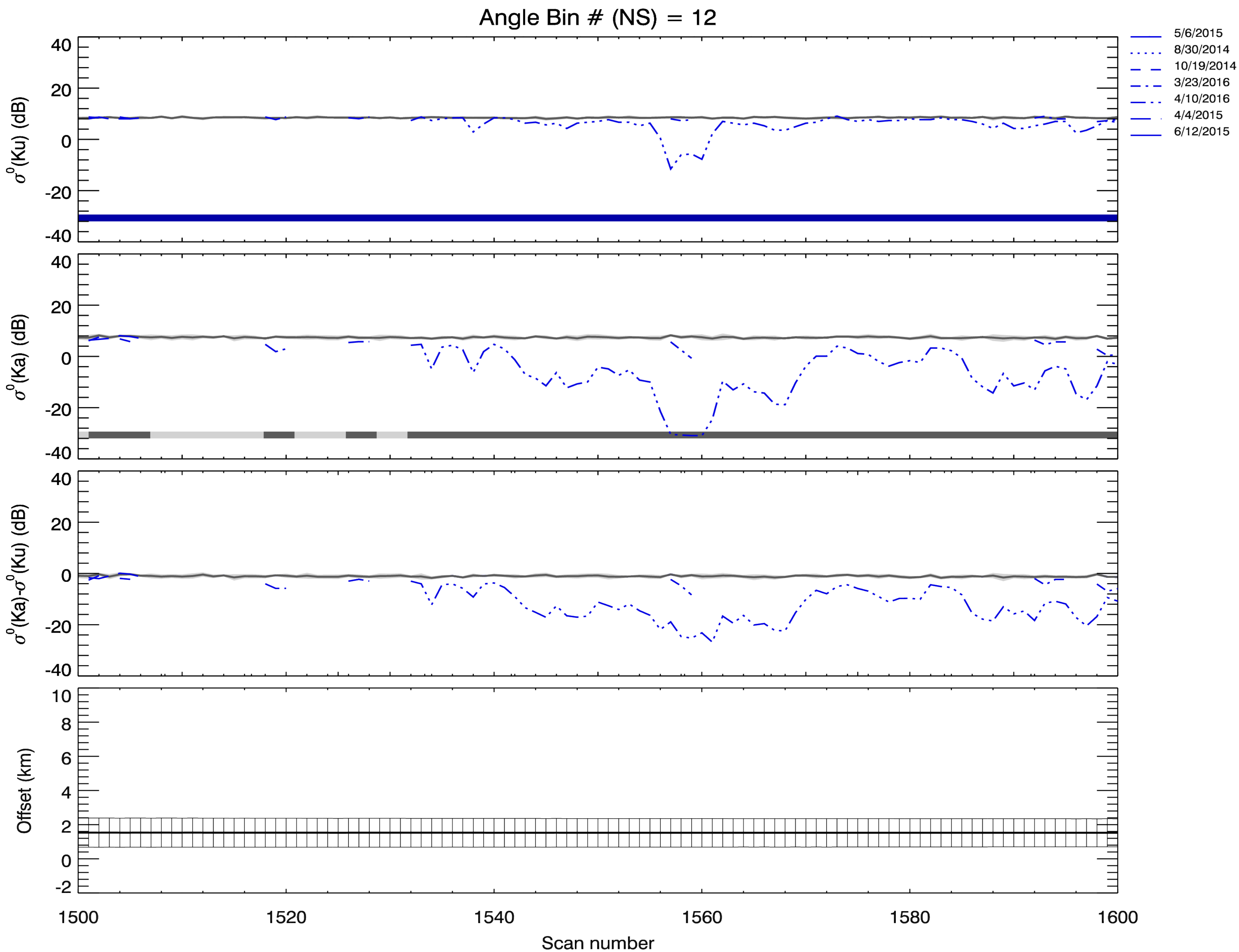


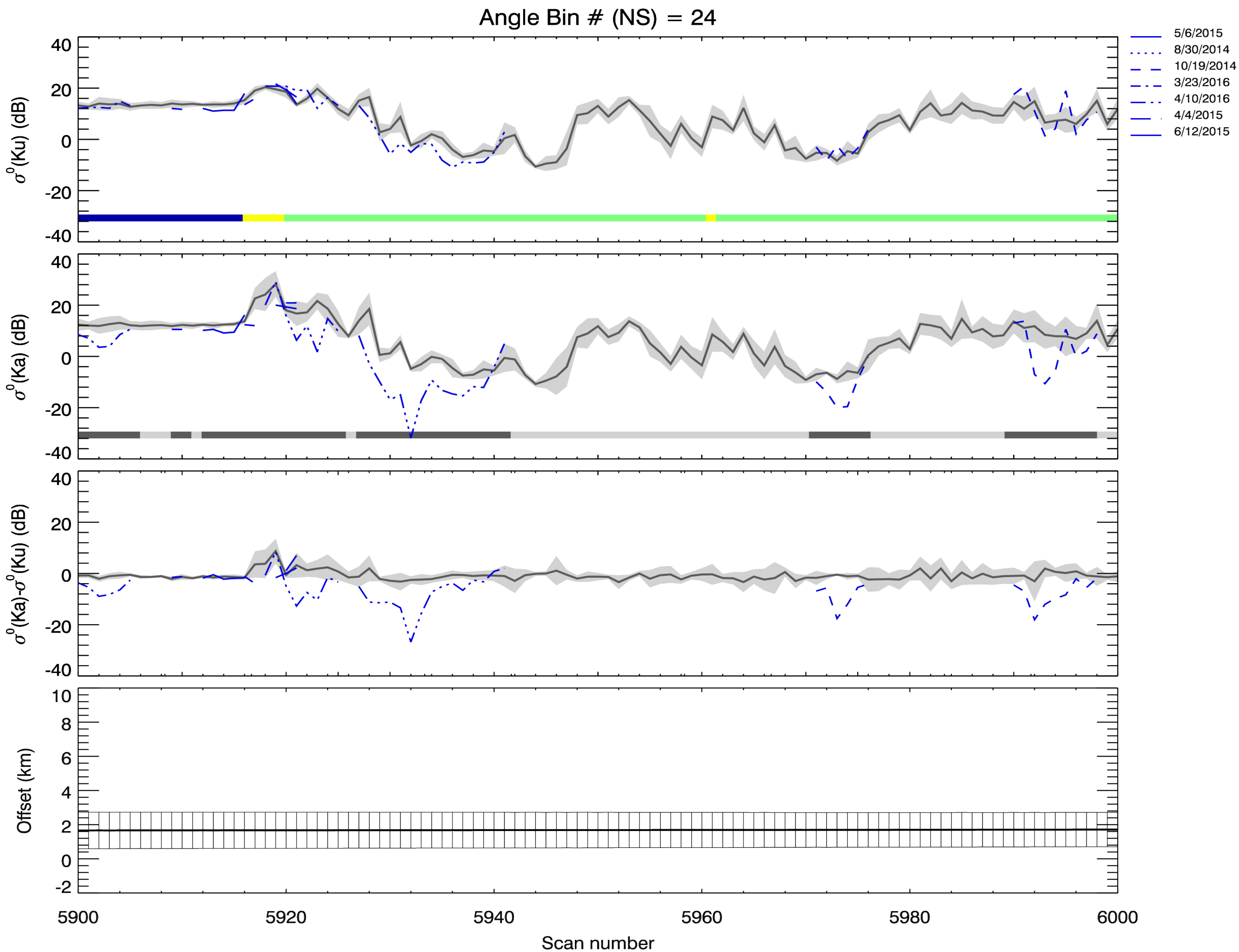
Angle Bin # (NS) = 36
5/6/2015
8/30/2014
10/19/2014
3/23/2016
4/10/2016
4/4/2015
6/12/2015
σ^0(Ku) (dB)
σ^0(Ka) (dB)
σ^0(Ka)-σ^0(Ku) (dB)
Offset (km)
Scan number



Angle Bin # (NS) = 24
5/6/2015
8/30/2014
10/19/2014
3/23/2016
4/10/2016
4/4/2015
6/12/2015
σ0(Ku) (dB)
σ0(Ka) (dB)
σ0(Ka)-σ0(Ku) (dB)
Offset (km)
Scan number


Angle Bin # (NS) = 24
5/6/2015
8/30/2014
10/19/2014
3/23/2016
4/10/2016
4/4/2015
6/12/2015
σ^0(Ku) (dB)
σ^0(Ka) (dB)
σ^0(Ka)-σ^0(Ku) (dB)
Offset (km)
Scan number
40
20
0
-20
-40
10
8
6
4
2
-2
1600
1620
1640
1660
1680
1700


Angle Bin # (NS) = 12
5/6/2015
8/30/2014
10/19/2014
3/23/2016
4/10/2016
4/4/2015
6/12/2015
σ0(Ku) (dB)
σ0(Ka) (dB)
σ0(Ka)-σ0(Ku) (dB)
Offset (km)
40
20
0
-20
-40
10
8
6
4
2
-2
1500
1520
1540
1560
1580
1600
Scan number



Angle Bin # (NS) = 24
5/6/2015
8/30/2014
10/19/2014
3/23/2016
4/10/2016
4/4/2015
6/12/2015
σ^0(Ku) (dB)
σ^0(Ka) (dB)
σ^0(Ka)-σ^0(Ku) (dB)
Offset (km)
Scan number
5900
5920
5940
5960
5980
6000